1696

ELEMENTS OF GALVANISM,

IN THEORY AND PRACTICE;

WITH A

COMPREHENSIVE VIEW OF ITS HISTORY,

FROM THE

FIRST EXPERIMENTS OF GALVANI

TO THE PRESENT TIME.

CONTAINING ALSO,

PRACTICAL DIRECTIONS FOR

CONSTRUCTING THE GALVANIC APPARATUS,

AND PLAIN SYSTEMATIC INSTRUCTIONS FOR

PERFORMING ALL THE VARIOUS EXPERIMENTS.

ILLUSTRATED WITH A GREAT NUMBER OF COPPER-PLATES.

By C. H. WILKINSON,

Lecturer on Galvanism in Soho-square, Member of the Royal College of Surgeons, of the Philosophical Society of Manchester, and Associate of the Institute of Medicine of Paris, Lecturer on Experimental Philosophy to the City Institution, Honorary Member of the Physical Societies of Guy's, Bartholomew's, the Lyceum Medicum Londinense, and of the London Philosophical and Mathematical Societies.

"ORATIONI ET CARMINI EST PARVA GRATIA, NISI ELOQUENTIA SIT SUMMA: HISTORIA QUOQUE MODO SCRIPTA DELECTAT."

PLINY, JUN.

IN TWO VOLUMES.

VOL. I.

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TO THE RIGHT HONOURABLE

SIR JOSEPH BANKS, Bart. K.B.

PRESIDENT OF THE ROYAL SOCIETY,

&c. &c. &c.

THE exalted station which you have, during so many years, filled in the Philosophical World, justly induced the illustrious Volta to announce his valuable discoveries in the Science of Galvanism under the sanction of your name. In being permitted to present to the world my comparatively trivial labours under the same distinguished sanction, I have the good fortune to secure for them a degree of attention, to which they might not have been entitled by their own merit.

Partial to the subject on which I treat, I had singular satisfaction to perceive, in the Letter with which you lately honoured me, that you duly appreciate its importance; that you consider it as

 highly

highly interesting, and its cultivation as promising the most important results to mankind.

Should this History of its Progress, and this attempt to arrange its interesting Experiments into a regular system, render the study of this Science more general, and cause its future improvement to keep pace with the past, I shall consider the time which I have devoted to it as profitably employed.

With every sentiment of gratitude for the distinction which, on this occasion, you have honoured me,

I am,

SIR,

Your devoted humble Servant,

C. H. WILKINSON.

19, *Soho-Square.*

PREFACE.

THE celebrated PRIESTLEY has shewn with what effect the study of several branches of useful Science may be facilitated, by his historical accounts of their rise, progress, and present state. Of the two methods of teaching Science, the Synthetical is, beyond all question, preferable to the Analytical; or, in other words, Science is the most rapidly conceived by a novice, when developed by the same steps as those by which it first became known to mankind. An example of this easy method of acquiring knowledge, is furnished by the first Part of the present Work; and an illustration of the successive principles will be found in the experiments detailed in the last Part.

Soon after the important experiments of GALVANI were announced, they were repeated and diversified by the most eminent Physiologists in every part of Europe. Their

opinions having been diffused through different philosophical publications, the selection and arrangement of such of them as have been deemed worthy of the Reader's attention, have been attempted in this present Work.

The valuable Essays which are diffused through the French, Italian, German, and British Journals, have been attentively examined, as well as the ingenious productions of SUE, REINHOLD, and HUMBOLDT: the excellent periodical productions, the *Medical* and *Physical Journal*, and the Journals of Messrs. NICHOLSON and TILLOCH, have proved the source of many useful observations; and the Conductors have, with a truly philosophical liberality, permitted the freedom of making every extract which might be deemed requisite for this Publication.

These materials I have not arranged systematically, but have principally been governed by the era of the original discovery. I have divided the Work into the two epochs which appeared the most interesting; the first consisting of the various disco-

discoveries, from the period of GALVANI to that of the Voltaic Pile; when the second epoch commences, and is carried down to the present time.

The Historical Details constitute the first Volume, and part of the second. The remaining portion I have devoted to the development of that particular theory which I have for some time entertained, and have adhered to the arrangement which I purposely made for the Lectures I have given upon this subject.

I have endeavoured to demonstrate the principles of Galvanism by those of Electricity. As, on this latter subject, I have presumed to entertain opinions contrary to those generally admitted, it has appeared to me absolutely necessary to set out by stating these opinions, before I should enter on the Elements of Galvanism.

On this account it is that, after having closed the History, I have commenced the Elementary Part by several Chapters on Electricity, with a view to the explanation of certain points, on which my ideas will be found to be somewhat novel.

This Work is illustrated by various Plates; and such descriptions and explanations are introduced, as will enable every attentive reader to construct his own Apparatus, and to repeat with facility any of the Experiments. In the medical application of Galvanism, I believe no person in England has been more extensively engaged than myself: the results of my observations materially differ from those of the Continental Practitioners. In many instances I have derived from its employment the greatest advantage; while, in many others, I have found it productive of no good effect. In some cases, I am even led to think it rather injurious than beneficial.

When, in the first instance, I entered on the medical application of this principle, I was led by the accounts of GRAPENGIESSER, and other foreign Physicians, to entertain the most sanguine hopes that it would prove one of the most active remedies we possess. Experience has taught me that my expectations were too ardent. It is probable, however, that my failure, in the

the cases in which it has been successfully employed abroad, may have originated from some circumstances of which at present I am not aware. I therefore trust that the statement I have made, will not discourage other Practitioners from its use, as it is only from the united labours of Professional Gentlemen, that its real utility can be ascertained.

There are many complaints, in which I have found the principle of Galvanism a most beneficial and powerful stimulant, greatly superior to any effects I ever experienced from Electricity. At a first view it may appear contradictory, on a supposition that both the principles are the same; that Galvanism, which is merely a weaker intensity of Electricity, should, notwithstanding, prove most active on the animal frame. The reason of this I have attempted to explain; and I am induced to think that the influence of Galvanism solely depends on the important agency it exercises in animal substances.

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THE

THE

HISTORY OF GALVANISM.

PART I.

CHAP. I.

The conjectures and hypotheses which were formed prior to the discovery of GALVANI—*Succinct account of his life—The incident which led him to the discovery of Galvanism—His experiments and conclusions—His hypothesis explained—Combated by other naturalists—Its application to medicine—Interesting observations made by* GALVANI *on the electricity of the torpedo.*

THE first printed notice which is to be found of the phenomena, since called galvanic, is in a work by SULTZER, published in 1767, under the title of "The General Theory of Pleasures."

The experiment explained by this writer, although distantly connected with the succeeding experiments, which we shall hereafter have occasion to describe, is so exceedingly simple, and may be made with so much ease, that it shall be given to the reader in his own words.

"If," observes SULTZER, "two pieces of metal, the

the one of lead and the other of silver, be joined together in such a way as that their respective edges may form but one plane, and if they be thus placed on the tongue, a taste will be perceived pretty similar to that of vitriol of iron; at the same time that either of these pieces of metal, when separately applied, does not leave any vestige of such a taste. It is not likely that, by this conjunction of two metals, a solution of either of them can take place, and that the particles dissolved in this way can penetrate into the tongue. It must therefore be concluded, that the conjunction of these metals produces on the one, or on the other, or, perhaps, on both, a vibration of their particles, which must necessarily affect the nerves of the tongue, and bring about the above-mentioned pleasurable sensation." In citing this experiment, the author aims at the illustration of the principles he lays down relative to the sensations, the first of which is, that "the mind is destitute of all sensation, without an analogous movement in the sensible nerves, in which the essence of the senses in general resides." His second principle is, that "every total sensation consists of a great number of momentaneous sensations, which succeed each other with such a rapidity, as not to admit any perception of the very minute spaces of time that elapse between them." The work of FABRONI on metallic irritation,

tation, and on the chemical action of the different metals on each other, founded on this experiment of SULTZER, will be analyzed in the sequel.

A fact connected with the science of galvanism, but anterior to its discovery, is related by M. COTUGNO, in the following manner *: A medical student, feeling a smarting sensation in the lower extremity of his leg, applied his hand to the part, and caught a mouse, by which he had been bitten. Having killed the little animal, he resolved to dissect it, and, touching with his knife a particular nerve (the intercostal), was not a little surprized to feel an electrical sensation sufficiently powerful to benumb his hand.

In reasoning on this fact, M. VASSALLI, member of the Royal Academy of Turin, conjectured that Nature is provided with some means to preserve and retain the electricity accumulated in any given part of the body of a living animal, to the end that she may employ it when occasion may serve. To confirm this opinion, he accordingly made several experiments, by which his theory seems to have been in some measure established, and the details of which were published in 1789. Several naturalists had already conceived

* Journal Encyclopedique de Bologne, No. VIII. 1786.

an idea that the blood is animated by the electric fluid; while others subscribed to the opinion of BRIDON, that the nervous and electrical fluids are one and the same. Such were the conjectures and hypotheses which had been formed, when the celebrated GALVANI, professor of anatomy at Bologna, instituted the experiments by which this subject has been so well elucidated, and which have suggested to physiologists new reasonings on muscular motion.

A succinct account of the life of this profound naturalist, ought necessarily to precede the details of the experiments which led to his important discovery. It is extracted from the Memoirs of the Medical Society of Emulation of Paris.

LOUIS GALVANI was born at Bologna, on the 9th of September, 1737, and commenced his studies at a very early age. Several of his nearest relatives had acquired much celebrity in theology and jurisprudence; and it was, in a great measure, under their tuition that he was instructed. Having completed his education, he took his degrees in physic; and soon after married the daughter of the learned Professor GALEAZZI. He was still young when he filled the chair of anatomical professor; and was very successful in comparative anatomy, more particularly in the dissection of birds; a treatise on the urinary passages

passages of which, he published. In this tract, he describes the position and form of the kidnies of the different varieties of the feathered race, their structure, envelopes, and substance, together with particular observations on the urinary bladder, ureters, emulgents, nerves, &c.

Such were the pursuits of this profound naturalist, before he was led to the discovery of galvanism. The latter part of his life was embittered by an uninterrupted series of calamities. After having spent thirty years with a wife whom he adored, and by whom he was equally beloved, he saw her expire in his arms. From a conscientious motive, he refused to subscribe to the civic oath required by the decrees of the Cisalpine Republic; and this scruple cost him the public employments he held, and the emoluments they brought with them. Death shortly after snatched from him, and that without allowing an instant of repose to the acuteness of his feelings, nearly the whole of his nearest and dearest relations. Finally, having himself been for a long time a prey to excruciating pains of the stomach, which were conjectured by his medical friends to proceed from an obstruction in the pylorus, this great man fell into a state of languor and decay, the rapid progress of which could not be checked by the professional skill and kind assiduities of two celebrated physicians

of Bologna, CINGARI and UTTINI. He died on the 4th of December, 1798, aged sixty years and about three months.

The incident which led him to the discovery of galvanism, or, as it has been otherwise denominated, animal electricity, has been variously related. The following account is drawn from a very respectable source, and appears to be nearest the truth. GALVANI being one evening in his laboratory, where he was employed in making experiments in the presence of a party of his friends, several frogs, which had been skinned, and were destined for soup, happened accidentally to be placed on a table, on which was also an electrical machine; between the conductor and the frogs there was a certain space. One of the company, who assisted at the experiments, having brought, unintentionally, the point of a knife into contact with the internal nerves of the thigh of one of these animals, the muscles of the limbs were instantly and powerfully convulsed. The wife of GALVANI being present, was struck by the novelty of this phenomenon, between which, and the disengagement of an electrical spark, she fancied that there was an agreement in point of time. On her making this observation to her husband, he resolved to ascertain the truth of so extraordinary a fact, and accordingly brought the point of a scalpel, or dis-

secting

secting knife, in contact with the crural nerves of one of the frogs, at the same time that a spark was drawn from the electrical machine. The result was, that the same contractions were manifested. As it was possible that they might have been owing to the simple contact of the scalpel, which might serve as a stimulant, rather than to the disengagement of the spark, GALVANI, to clear up this doubt, touched the same nerves of several of the frogs, while the electrical machine was in a state of rest. The contractions which had heretofore been observed did not ensue.

From this phenomenon GALVANI drew the following conclusions. The necessity of a conducting body for the production of the phenomenon in question. The advantage which results from giving a certain extension to the conductor, to produce the contractions. The various directions of the electrical influence, and the utility of the application of conducting bodies to the muscles. The efforts made to prevent the passage of the electricity. And, lastly, the proofs which had been obtained, that the communicated electricity is transmitted through the substance itself of the conductors. Having repeated his experiments with great assiduity, he was led, not merely to ascribe to electricity the phenomenon of the muscular contractions of frogs, but also

to determine, to a certain extent at least, the laws by which this species of electricity is governed *.

This property of the spark, by which muscular contractions are excited, inspired GALVANI with a wish to examine whether the battery of FRANKLIN, when discharged, would be capable of exciting contractions of a still more powerful nature. His attempt, however, proved ineffectual. He afterwards made experiments with negative electricity, and for this purpose had recourse to the electrophorus of VOLTA. He endeavoured to intercept the course of the electric fluid, which acts on the animal or on its conductors. To the end that he might come to a more direct and precise knowledge of his subject, he operated on the living animal, and obtained weaker commotions than when the animals subjected to his experiments were dead. In this investigation he cut off the communication of the surrounding air; and having made choice of animals with warm blood, namely, fowls

* It is remarked by PFAFF, in his work entitled *Uber Thierische Electricitaet und Reitzbarkeit*, p. 333, that the origin of the muscular contractions of frogs is explained by the stimulating force of common electricity, which acts, in this instance, by communication; and that it is unnecessary to have recourse to an animal electricity, in seeking to explain such a phenomenon.

fowls and lambs, found that the results were invariably such as he had obtained when his experiments were made on cold-blooded animals. The nerve having been dissected, and carefully separated from the surrounding parts, he applied to it the conductor, and, on the discharge of the electric spark, the contractions were instantly manifested.

The numberless trials made by the learned Professor of Bologna seem to demonstrate, that among living animals those are in general the best calculated to manifest the contractile movements, who are of a more advanced age, as well as those whose muscles are of a whiter substance. The success of the experiments depends much, however, on the mode in which the animal is prepared *."

Having made these discoveries on the influence of artificial electricity on animals, GALVANI next endeavoured to ascertain, whether the electricity of lightning would be productive of the same effects in the movements of the muscles. The

* ALIBERT, the eloquent writer of the eulogy on GALVANI, from which this article is extracted, in speaking of the irritability of frogs, observes, that it is not every where the same, and that there must necessarily be a variety in the results of the experiments, according to the different countries, those of Europe even, where these experiments are made.

result

result of these experiments was precisely the same as in the application of the former; and he found that the contractions augmented in proportion to the intensity of the flashes of lightning, and to the proximity of the electrified cloud.

The most interesting, as well as the most useful of the epochs by which the glorious enterprizes of GALVANI are marked, is the one in which he demonstrated, by a variety of ingenious experiments, the influence of metals on the movements of the muscles, whether in the open air, or in a confined atmosphere. He began to suspect the possibility of an appropriate and inherent electricity in the system of animals, and conjectured that the nervous fluid passes from the nerves to the muscles, by a law analogous to the one which governs electricity in the experiment of the Leyden phial. He employed successively a repressing arc and a conducting arc, the latter of which excited the contractions, while it was impossible to produce them by the means of the other. Similar contractions were excited, and were in many instances still more powerful, when, instead of a single arc, two were employed. They were so disposed as to touch, each by one of its extremities, the one the nerves, the other the muscles of the animal, while the two remaining extremities were brought together

ther and connected at will. To produce the desired phenomenon of contractions, GALVANI thought it essential to employ different metals; and in this way he was enabled to ascertain the influence of similar or dissimilar metals on the contractions which ensued.

It was no less important to inquire, whether these contractions resulted from the *positive* or from the *negative electricity*; and whether, in such a case, this principle is latent in any single and homogeneous metal, or is inherent in the animal. GALVANI made his experiments in different *media*, or intervening substances, and convinced himself that water performs a function analogous to that of the arcs, but that this observation does not apply to oil. Hence he considered himself as justified in the conclusion that two states of electricity are contained in the animal, one of which resides in the muscles, the other in the nerves; or, perhaps, that both of them reside equally in each of these component parts of the animal economy. His next endeavour was to ascertain the true seat of this electricity, and more particularly the nature of that which resides in the nerves. He accomplished this, by noticing the influence of the extent of the surfaces of the coatings on the intensity of the muscular contractions.

After a variety of researches on the true seat of electricity in the animal system, GALVANI examined the relations which subsist between that electricity and the electricity properly so called. He examined the various degrees of the conducting property, as it exercised itself on the different substances employed in the experiments, and in following up his inquiries into this property, as it acts on the different parts of the animal, found it to reside both in fluid and solid bodies, but not in oleaginous liquids.

It is not difficult to conceive, that the earliest author of Galvanic experiments should also be the first to establish an hypothesis on the phenomena he had noticed. Although the one which GALVANI has formed has been adopted by a very inconsiderable number of naturalists, while it has been combated by several others, and absolutely rejected by the great majority, still there are two powerful reasons why it should not be passed over in silence, seeing that it forms a part of the labours of this profound and sagacious inquirer, and that, when it was conceived by him, he flattered himself that he had discovered one of the most important secrets of animal organization, and of animal life. In entering on the subject of this hypothesis, it ought to be observed, that the authors who have treated of galvanism may be classed under two distinct sections,

sections, relatively to the theoretical ideas they have entertained. While a part of them have, in common with GALVANI, been enabled to discover in galvanism nothing more than a phenomenon essentially dependent on the parts of the animal; the others, at the head of whom VOLTA may be placed, have considered the galvanic action as a general phenomenon of Nature, which manifests itself solely by the intervention of the irritable and sensible fibre, and is not subordinate to the vital energy. In the physical sciences the facts are immutable; but the hypotheses which are employed to explain the mode by which they are generated, are susceptible of an infinite variety.

"The nerves," observes GALVANI, "which are distributed in the different parts of the muscular system, and which receive or transmit the electrical fluid, have all of them a common origin in the cerebral organ; and it is not probable that these nerves, the structure of which is so varied in the universal economy of animals, should be the secretory organs of an homogeneous fluid, such as the one destined to excite the muscular contractions." He consequently supposes, in the first place, that all animals are endued with an inherent electricity appropriate to their economy, which electricity, secreted by the brain, resides especially in the nerves, by which it is com-

communicated to every part of the body. And, secondly, that the principal reservoirs of this electricity, which he calls *animal*, are the muscles, each fibre of which ought to be considered as having two surfaces, and as possessing on this account, both a positive and a negative electricity, at the same time that it, in a manner, represents a small Leyden phial, the nerves with which it is provided being the conductors.

The mechanism of the various movements is explained by GALVANI in the following manner: The electrical fluid is drawn and attracted from the interior of the muscles into the nerves, from whence it afterwards passes to the external surface of the muscles; insomuch, that each discharge of this description of electrical phial is followed by a muscular contraction, which is the effect of the *stimulus* produced by the electricity. He was strengthened in this conjecture by the perfect analogy he fancied he could perceive between the phenomena of the Leyden phial in electricity, and the muscular contractions. However this parallel may have been since weakened by a few isolated facts, or rather, by the conclusions which have been drawn from them, it is certain that there is a striking similitude in the principal points.

It would have been equally fortunate for GAL-

VANI, and for the medicinal science, if, with the powerful resources of his inventive genius, he had succeeded in the principal extensions he gave to his first hypotheses, in the investigation of the causes of diseases, and had realized his particular ideas relative to the production of rheumatic affections, of the nervous sciatica, and of convulsions and tetanus. These ideas, and their application to medicine, will be developed in the sequel of this work. In conformity to the theory he had established, he endeavoured to explain the proximate cause of paralysis, apoplexy, and epilepsy; and was of opinion that the good effects resulting from the administration of various remedies in the above diseases, and, among them, the application of artificial electricity, were, in certain cases, to be ascribed to the mode of action of these remedies on the animal fluid, whatever might be the change brought about in the state of the latter. It therefore appeared to him that the physician ought to be governed by this intention of cure, in the treatment of his patient; and, in the case of convulsive diseases, he considered that it was of the highest importance, to inquire which of the two states of electricity, the positive or the negative, it would be most expedient to employ.

After having described the new mode of applying the latter of these states of electricity, which he

he found of great utility in rheumatic and other analogous affections, GALVANI proceeded to expatiate on the advantages which might result, under similar circumstances, from the electricity of the atmosphere in stormy weather, provided the utmost caution and prudence should be observed in arming with conductors the affected part. It was in this way that he explained the sudden and extraordinary recovery of the use of the limbs, in cases of paralysis, in consequence of the lightning having burst at a very inconsiderable distance from the spot where the persons labouring under the paralytic affection resided. Are not, however, these spontaneous cures, supposing them to have happened, rather to be ascribed to the emotion of terror, which a loud clap of thunder excited in the suffering individual? To such a cause may be ascribed the case related in the physiology of DUMAS, of the cure of a man, who, at the time his house was on fire, recovered the use of his feet, by the consternation into which he was thrown.

It has already been remarked, that the theory of GALVANI met with several adversaries among those even who had admired and repeated his beautiful experiments. One of the most redoubtable of his antagonists, was the celebrated Professor VOLTA, who made several ingenious attempts, to prove that there does not exist a particular electricity

electricity inherent in the system of animals, and that the living body ought simply to be considered as a humid substancce or conductor. In two memoirs addressed to SPALLANZANI, GALVANI replied to the objections of VOLTA, and established, by new experiments which are there described, the numerous characteristics which, in conformity to his theory, mark the differences and distinctions between animal electricity and common electricity. His arguments were principally founded on the phenomena of the muscular contractions, which may be manifested independently of the heterogeneity of the metallic substances, necessary in no other case, unless when frogs, the vitality of which had been weakened in a very considerable degree, were employed in the experiments. He afterwards had recourse to non-metallic substances as conductors, and found that the immediate contact of the heterogeneous coatings was not absolutely necessary to excite the contractile movements.

To the new objections made to his theory, GALVANI replied by new experiments, and by the consequences he drew from them*. After having

* BRUGNATELLI's Annals of Chemistry and Natural History, vol. xvi. contain two anonymous letters on galvanism, or rather, according to the author, on the pretended animal electricity

having endeavoured to prove that all the phenomena of animal electricity depend on a particular circle established in the muscle, by the means of the nerve and the arc, he developed the manner in which this circle is effected; and having dwelt on the analogy between the laws by which it is governed, and those of the Leyden phial, electric battery, &c. he endeavoured to demonstrate the reality of this circle under all the circumstances in which it is brought about, and to prove that it follows the route of electricity in proportion as it runs through the parts subjected to experiment. This is the aim he had in view when he published a memoir replete with curious and interesting facts, which would not, however, be well comprehended without the plates by which they are accompanied.

Professor PFAFF, of Kiel, displayed much

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city said to result from the galvanic experiments. The author defends the opinion of VOLTA on the nature of the galvanic fluid, and endeavours to prove that its effects are precisely the same with those of natural electricity; that this fluid is excited by the contact of different conductors of various descriptions, but principally by that of metallic conductors, that it may be rendered positive and negative; and, lastly, that it can be measured with the electrometer. This defence of VOLTA is principally levelled against GALVANI himself, he having recently published a work in which he insisted on the peculiar nature of the fluid he had discovered.

ability in the attempts he made to refute the opinion of GALVANI. He endeavoured to prove that the idea of a positive and negative electricity in the interior and exterior of the muscles, is not founded on any decisive fact, and that the greater part of the galvanic phenomena are either not to be explained by this theory, or are directly opposed to it. The professor of Bologna, observes PFAFF, establishes a circulation of positive electricity from the interior of the muscles to the exterior, by the means of coatings and other conductors, and fancies that it is owing to the re-establishment of the equilibrium between the internal and external parts, by the means of this positive electricity, thus brought into action, that the muscular contraction is produced. All the experiments, however, in which the two coatings are applied to the nerve only, without its having been moistened, or in a desiccated state, and without a correspondence being kept up between it and the muscle by a conductor, are in a manner contrary to the hypothesis of GALVANI.

The experiments, continues the professor of Kiel, on the effects of the ligatures of the nerves, are likewise so many objections to his theory. The crural nerve being isolated, and bound in the middle, and the coating applied above the ligature, the contractions are manifested when an exciting arc of another metal is brought in con-

tact, either with the nerve above the ligature, or with the muscles and the coating, it being constantly supposed, that the arc necessary to the developement of the muscular contractions is in this manner formed. It results from hence, that in this case, the ligature does not intercept the circulation from the interior to the exterior, &c.

Another objection made to the theory of GALVANI by professor PFAFF, is founded on the contractions which are produced, as well at the instant when the galvanic arc is closed, as at the moment when it is opened. If these contractions, he observes, take place at the moment when a communication between the interior and the exterior of the muscles is kept up by the galvanic arc, and the equilibrium between these parts of the muscles on that account necessarily re-established, it is not easy to conceive how, the re-establishment of the equilibrium having taken place, the effect should be the same as when, an instant after, the galvanic arc is opened. This, however, he observes, is what constantly happens; and there are even circumstances in which the effect is much more powerful when the arc is opened than when it is closed; supposing, nevertheless, that this effect is concentrated on the force of the contractions.

According to the above naturalist, the theory of GALVANI does not explain the influence pro-

duced

duced by the diversity of the coatings, as well as by the manner of distributing them to the nerves and the muscles, on the appearance and energy of the contractile movements. He is also of opinion, that it does not illustrate the experiments made on the organs of the senses, &c. &c.

Such are the principal objections of professor PFAFF to the theory of GALVANI. Since the mass of facts has been augmented by the united efforts of physiologists, many others, which will be detailed in their proper places, have been added.

However his theory may have been combated, it is certain that the discovery of GALVANI has, from its origin upwards, given rise to several curious observations and interesting discoveries, which it would be highly improper to pass over. By the experiments which have been made, it has been seen, in the first place, that the muscles of animals exposed to gangrenous miasmata are not contracted, at the same time that contractions are excited in the muscles of animals exposed to the action of the different gases and poisons. This proves, that the putrid miasmata attack the principle of irritability more powerfully, and with a more fatal effect, than do the poisons and the gases. Secondly, that drowned animals have been restored to life by the excitement in their system of the action of the nervous fluid. This

is an additional proof, that in the cases of drowned persons, as well as in asphyxies, the principle of irritability has been attacked. Thirdly, that animals on whom a considerable number of experiments have been made, and who have consequently been exhausted, sooner become putrid than other animals. This supplies an additional evidence in support of the opinion, that in putrid fevers the nervous fluid is either changed or diminished. Finally, the conjecture of M. VALLI, that the nervous fluid is not secreted from the blood, as appeared to be demonstrated by analogical reasoning, but is drawn from the atmosphere and from the earth, is in a great measure confirmed. By this hypothesis it is not difficult to explain, how it is that animals who have remained during several weeks without food, and without renewing their blood, have been enabled to preserve for so long a space of time the faculty of motion.

It must, however, be acknowledged, that several of the phenomena of the galvanic fluid, and more especially the instantaneous mode in which it is transmitted, brought about and favoured as it is by certain substances, while it is prevented by others, establish a remarkable similitude between the laws by which this fluid is governed, and those inherent in the matter of electricity. It is at the same time equally certain, that other consi-

considerations, as will hereafter be seen, present themselves to destroy this identity, and to separate, in their essential qualities, these two individual properties.

It has been seen above, that GALVANI made a considerable number of experiments, with a view to prove that a destruction of the equilibrium in the electricity of living bodies, does not result from the heterogeneity of the metals or other substances with which the limbs of the animal may be coated. He went still farther, and endeavoured not only to appreciate the action and influence of this heterogeneity of the coatings on the intensity of the muscular contractions, but also to establish several conjectures drawn from the phenomena he had discovered and pointed out. In illustrating this subject, he remarked, that he had even obtained movements without a coating, and that by the simple application of the extremity of the arc, the diameter of which was almost insensible. He was of opinion, that the action of the heterogeneity takes place over the electrical torrent, which, in condensing, must necessarily pass by the extremities of the arc. He afterwards tried to ascertain the nature of the mode of action of the heterogeneity of metals on the electrical torrent, and imagined that the sole influence it possesses, consists in augmenting either the quality, or the

velocity of the latter. Having reduced to three causes, which he developes with much sagacity, the results of these and similar effects, he afterwards proceeded to examine why, and in what manner, the want of contiguity contributes so powerfully to augment the energy of the muscular contractions. This effect he ascribed to the resistance opposed to the passage of the fluid by the small layer of air interposed between the two metals; and observed, that by the diminution of this layer of air, the developement of the contraction is facilitated. He employed the same principles in explaining a phenomenon which is somewhat curious and remarkable, namely, the contractions which result from the experiments made with a single homogeneous coating, to which one of the extremities of the arc of a similar nature is applied, at the moment when the other is in contact with the part of the animal in a bare state. By a similar theory GALVANI accounted for the curious experiment made with a drop of water.

In a memoir* which contains a complete exposition

* *Aloysii* GALVANI *de viribus electricitatis in motu musculari commentarius, cum* J. ALDINI *dissert. et notis. Accesserunt epistolæ ad animalis electricitatis theoriam pertinentes. Mutinæ*, 1792. This commentary is preceded by a dissertation

position of his discovery, GALVANI published several interesting remarks on the electricity of the torpedo. From the earliest date of his discovery he had paid a particular attention to the productions of REDI, REAUMUR, WALSH, JOHN HUNTER, and SPALLANZANI, in which this important subject is investigated; and took advantage of the new data he had acquired on the subject of metallic irritation, to go still farther than his illustrious predecessors in this particular tract of science. In a voyage he made to the Adriatic Sea, he had a convenient opportunity to multiply his trials, which became the subject of a learned dissertation. His experiments being, however, more immediately connected with common electricity, than with galvanism, it will be

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tion by ALDINI, on the origin and progress of animal electricity. It is divided into four parts, in which the following subjects are treated: First, the power of artificial electricity on muscular motion. Secondly, the power of atmospherical electricity on the same. Thirdly, that of animal electricity on the above muscular movements. And, lastly, the conjectures hazarded by the author, and the consequences he draws from the above subjects. The plates by which this memoir is illustrated, are three in number, and contain twenty-seven figures. It is followed by a letter from M. CARMINATI, professor of medicine at the university of Pavia, to the author, on the subject of the different opinions held by the latter, and by VOLTA, relative to the true seat of animal electricity.

sufficient

sufficient in this place to observe, that the most interesting of them are those made by GALVANI with prepared frogs. These frogs having been laid on different parts of the surface of torpedoes, and disposed in various directions, were all of them thrown into a convulsed state at the same moment. He obtained the same result from his subsequent experiments on the muscles and heart of frogs placed on torpedoes; and established a new point of analogy, heretofore unknown, between the electricity of the torpedo and common electricity.

GALVANI, constantly occupied by his favourite hypothesis, made several other experiments on animal electricity, with a view to ascertain whether it is provided with a stimulating power similar to that of common electricity, or of the electricity of the torpedo. In examining its action, he had recourse in the first instance to the muscles, his experiments on which appeared to him to demonstrate that the phenomena of animal electricity are precisely similar to those of the above cited electricities, and that it is consequently endued with the same stimulating property. Before he drew this conclusion, however, he made several experiments on the nerves, which are acted on and irritated with greater ease than the muscles. The only result he obtained from these experiments, which were conducted

ducted with great ingenuity, was the existence of the electric fluid in the galvanic arc. He contended, that this fluid irritates in its passage, all the parts of the animal of which the arc is composed. It has, notwithstanding, been proved by recent experiments, that the parts of the animal do not essentially possess the faculty of supplying and inculcating this fluid.

Such were the experiments of GALVANI, and such the conclusions he drew, with a view to the establishment of his hypothesis relative to the existence of animal electricity. We shall now proceed to detail the labours of other naturalists on the same subject; following, as nearly as may be, the order of time in which their experiments were made.

CHAP. II.

Experiments of M. VALLI *on animal electricity, as they were repeated by the late French Academy of Sciences, and by the Royal Society of Medicine of Paris—These experiments were made, as well on animals with hot blood, as on cold-blooded animals.*

M. VALLI, an Italian physician, was, among physiologists, one of the earliest to enter on a series of galvanic experiments, which he began by those that relate more immediately to animal electricity. The result of these experiments he communicated in 1792 to the late French Academy of Sciences, by the members of which the experiments themselves were so much approved, that the greater part of them were shortly after repeated in the chemical laboratory of FOURCROY. They are as follows:

Experiment I. Two metallic coatings, one of lead, the other of silver, were placed on a frog fastened to a table, the former on the belly of the animal, the latter on the pelvis. These metallic coatings having been brought in union by the means of an exciting arc of copper, very power-

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ful convulsive movements were produced in the animal.

Experiment II. The small sheet of lead employed as one of the coatings in the former experiment, having been removed, so as to leave the abdomen bare, and the exciting arc applied in the same way as before, the convulsive movements took place, but were not so sensible as in the other case. The author candidly avows that this experiment does not always succeed.

Experiment III. In employing two coatings of the same metal, silver or gold for instance, it was found that the effects produced by the exciting arc of copper were much weaker. When these coatings were not only of similar metals, such as copper, lead, tin, zinc, &c. but the exciting arc also, no effect was produced.

Experiment IV. The coating placed on the abdomen having received an horizontal direction, insomuch that the points of contact were less numerous, the effects were proportionally diminished. As soon, however, as the coating was brought into full contact with the surface of the abdomen, they became as powerful as heretofore.

Experiment V. A frog having been skinned, and cut transversely through the middle, the nerves of the thighs were laid bare, united, and placed on a piece of gold, at the same time that the thighs themselves were brought in contact with

with a piece of silver. On the application of the exciting arc of copper slight movemets were produced; as they also were when both the coatings were of silver. But when a coating of tin, lead, or copper, was substituted to the one of silver in which the nerves were enveloped, the movements became very violent. The following gradation was, however, to be observed in the action of the metals: the lead produced the most powerful movements; next, the tin; and, lastly, the copper. In proportion as the vitality of the frog was diminished, the metals also lost the power of governing the direction of the progress of the electric fluid in the animal. The lead, tin, and zinc, preserved this property the longest.

Experiment VI. Plummers' lead, placed on each side as a coating, produced no effect when employed with an exciting arc of the same description of lead; but when different qualities of this metal were selected, such, for instance, as the lead of the assayer, and plummers' lead, an exciting arc of either of these descriptions of that metal produced very singular effects. When these two kinds of lead, in changing the different metals, were no longer productive of any effect in one of the coatings, by substituting to the lead either silver, gold, bismuth, antimony, or zinc, movements of so powerful a nature were obtained as to enable the animal to be susceptible of

of slight convulsions, when the above-mentioned pieces of lead, each of them of a distinct kind, were again applied.

Experiment VII. A short interval of repose having been allowed to the frog, it was found to be susceptible of convulsive movements of a forcible nature, when again subjected to the same trials.

Experiment VIII. The electric power being nearly exhausted in this animal, it was found that the different metals, when they produced by their contact new convulsions, did not, on this effect ceasing, leave to the animal the faculty of displaying fresh movements with the coatings of the different kinds of lead above-mentioned.

Experiment IX. Lastly, the electric action disappeared totally in the following order, the plummers' lead invariably forming one of the coatings: the assayers' lead first ceased to determine the action; next, the tin; next, the antimony; next, the zinc; next, the copper; next, the gold; and, finally, the silver. It ought here to be noticed, that the iron had lost its exciting quality before the antimony; but it was not ascertained whether it had likewise been deprived of this quality before the lead and the tin.

Experiment X. The zinc, in losing the exciting property by which convulsions had been produced on the frog, which had been subjected

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to the experiment for the space of an hour, was not capable of determining any farther movement when the leaden exciting arc was placed on it. It was, however, remarked, that movements were still produced by this metal the moment the person engaged in the experiment removed the exciting arc, and destroyed the communication. This singular experiment was so often repeated, as not to leave any doubt respecting the result.

Experiment XI. The upper part of a frog, skinned and intersected transversely, having its crural nerves armed with a piece of lead, as in the preceding experiments, was placed in a glass filled with water, while the inferior part of the animal was placed in another glass. The different parts displayed very powerful movements when the communication was established by the means of a chain formed by the company, two of the persons present having been selected to touch, each of them the water in one of the glasses. One of these individuals held in his hand a bit of metal, which he brought in contact with the coating of lead.

Experiment XII. When one of the company withdrew himself in such a way as to interrupt the chain, the movements were no longer perceptible.

Experiment XIII. The parts of the frog having

ing been placed in the two glasses, as in *Exp.* XI. the operator could not excite any movement by establishing the communication with his two fingers. He was equally unsuccessful when, with one hand armed with a piece of metal, he touched the body of the frog, while he placed a finger of the other hand on the metallic coating of the crural nerves. But when, having a finger placed on the inferior part of the frog, he presented the piece of metal to the coating of the nerves, very powerful movements were excited in the animal.

Experiment XIV. When the frog was touched with a metallic exciting arc in an insulated state, no sensible effect was produced; but when the metal ceased to be insulated, the effect was invariably very considerable.

Experiment XV. One of the fore legs of a rabbit having been detached from the body, the brachial nerves were denudated, and armed with a piece of sheet-lead. A piece of silver, which was to act as an exciting arc, was afterwards laid on an adjacent muscle; and the result was, that very violent convulsive motions were produced in the animal. In this experiment on the rabbit, as it was afterwards varied, one of the coatings being of plummers' lead, and the other of assayers' lead, the movements were no longer excited. When they consisted, the one of lead, and the other of iron, they produced as little

 effect;

effect; but when the lead, as one of the coatings, was tried with another coating, either of silver, gold, copper, zinc, or antimony, convulsive movements were produced. Combined with a coating of bismuth, the coating of lead produced but very slight movements.

Experiment XVI. To ascertain the state of the electricity inherent in the animal subjected to the experiment, it was plunged into a vessel containing one of Coulomb's electrometers, and successively electrified both positively and negatively. In either of these cases the animal influenced the balls of the electrometer, so as not only to evince that the electricity was in a perfect state of rest, as well before as during the experiment, but also, that the system of the body on which it was made, presented, in the most marked and striking manner, the phenomenon of a Leyden phial.

Experiment XVII. The left crural nerve of a living frog having been bound by a strong ligature, the animal lost the faculty of moving in a natural way, the part beneath the point where the ligature was tied. The nerve, however, having been armed in the same manner as in the preceding experiments, the movements were excited as soon as the communication was established between the muscle and the part above the ligature.

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Experiment XVIII. The ligature having been made on the left crural nerve, sufficiently near to the muscle to be in contact with it, and on the right crural nerve in such a way as to render it disengaged and visible, the left part of the animal, being in a palsied state, remained perfectly motionless, while the convulsive movements excited by the communication were all of them confined to the right side. The above-mentioned left crural nerve having been afterwards more effectually denudated, and separated from the muscular substance by which it was surrounded, recovered its quality as a conductor, and permitted the movements which were communicated to display themselves with considerable energy. When the ligature was forced back against the muscle, the limb again lost the faculty of motion.

Experiment XIX. One of the crural nerves having been armed with a piece of sheet-lead, a communication was established between this nerve and the other crural nerve in an unarmed state. The result was, that very powerful convulsive movements were produced.

Experiment XX. One of the above nerves, coated with two pieces of lead, at different intervals of the muscle, was violently agitated as soon as a communication was established between the two parts by the means of an exciting arc. The

same effects were observed, notwithstanding every part of the nerve was laid bare, and separated from the surrounding muscle.

Experiment XXI. An attempt was made to establish the same communication in experimenting on a living animal with hot blood, a guinea pig. The result was not, however, so satisfactory as there was reason to expect.

About the same time that the above experiments, as they had been described by Dr. VALLI, were repeated by the French Academicians, they were also made before the late Royal Society of Medicine of Paris. On this occasion M. MANDUYT, distinguished by his talents and industry in the application of electricity to the healing art, was present. He was led to consider the effects which resulted from the experiments as dependent on common electricity; but was at the same time of opinion, that they proved two additional facts. In the first place, that the metals were charged with a different quantity of the electric fluid, insomuch, that when they were brought in contact with each other a discharge ensued. And, secondly, that the animal body, by which the electric fluid is rendered perceptible, is a more delicate electrometer than any one heretofore discovered.

CHAP. III.

In the progress of his new experiments, M. VALLI *observes all the phenomena noticed by* GALVANI *—The electricity of animals independent of their vitality—The presence of the electric fluid necessary to the existence of men and animals—Experiment made with a view to ascertain the identity of the nervous and electric fluids—Observations of* FONTANA *on the movement of the heart—Reflections of* M. DE LA METHERIE *on animal electricity.*

THE experiments of Dr. VALLI, given in the preceding chapter, were followed by several communications made by him to the editors of the French Philosophical Journal (Journal de Physique.) The following is the substance of his letters, which contain several new and very interesting experiments.

In his earliest communication, M. VALLI contents himself with describing the phenomena he had observed in prosecuting his experiments, without attempting to establish any theory, or to derive any of those consequences which would have required a greater body of facts than were

as yet collected on the subject of animal electricity. He notices, that he had observed all the phenomena perceived by GALVANI; and that they had alike taken place on the animal, whether in an insulated or in a non-insulated state, by the means of conductors of different metals, the successive changes of which had rendered the electric commotions more manifest. He acknowledges, notwithstanding, that the conductors of silver had constantly appeared to him to produce a more sensible effect than the others.

Being desirous to ascertain the space of time during which frogs were enabled to resist the fatigue and sufferings resulting from the experiments, Dr. VALLI prepared two frogs at ten o'clock at night. On the following morning, at seven o'clock, they were extremely feeble, but not without movement. In both of them weak convulsions were produced by the common experiment. At the expiration of another hour they ceased to give any farther sign of vitality, in spite of all the efforts which were made for their resuscitation. On several subsequent occasions, prepared frogs having been left during the night, were found in a desiccated state the next morning, and ceased to give any sign of vitality. After having separated several of the muscles from the body of a frog, and having torn them, it was impossible to excite their irritability by a mecha-

mechanical stimulus; but this was effected by the medium of the conductor.

On this subject, Dr. VALLI proposes two questions. In the first place, whether the movement of the muscles, produced by irritation, or by the nerves with which these muscles are provided, is different from the one which results from the discharge of the electric fluid? And, secondly, which of these movements has the greatest affinity to those that are voluntary?

The results of thirteen experiments made with opium, which was employed in different ways, both internally and externally, were very different from each other. In an experiment made with powdered tobacco, four frogs, which had by this mean been rendered insensible to tortures, and were in a state of the completest stupefaction, were nevertheless made to display symptoms of vitality, on the application of the exciting arc. Several lizards, poisoned with tobacco, and which were convulsed at the time of their death, did not lose their electricity. A variety of experiments were afterwards made on different animals and fishes, namely, on cats, dogs, eels, tenches, &c.

M. VALLI having noticed in his details, that the ligature made on the nerve presented an obstacle to the passage of the electricity, M. FATTORI, a naturalist, apprized him that this

was not an invariable consequence. He accordingly repeated his experiments, and observed that the ligature of the nerve, made close to its insertion in the muscle, entirely impedes its movement; but that if, on the contrary, it is placed at a distance from the muscle, the experiment succeeds perfectly well, every part of the animal becoming a conductor of the electricity.

A very singular fact, which deserves the particular attention of naturalists is, that the tremulous motions produced in the animal by the means of the exciting arc, are generally more powerful if this arc be carried from the muscles to the coating, than if it be conveyed from the coating to the muscles. If the latter mode be employed at a time when the electricity is so weak as to be nearly in an exhausted state, it will be impossible to excite the movements which will be readily obtained by the former process.

Slight wounds inflicted in the brain of frogs, occasionally cause them to become convulsed, while at other times they render them paralytic, and at others, again, are not attended by any such serious consequences. In some instances the animal perishes suddenly from the injury; in others, at the expiration of a few hours; and again, in others, survives for several days. Frogs which have long been subjected to the operation of the conductor, more especially in water, suddenly

denly fall into a corrupted state. How extraordinary will it be, observes M. Valli, if hereafter it should be found that the electric fluid retards putrefaction, and resists the dissolution of bodies! Prior to the discovery of galvanism, it was known that the fluid which circulates in the nerves is a powerful antiseptic.

Inflammable air, or hydrogen gas, extinguished in a small bird, a fauvette, the vital principle, but did not destroy its electricity. The fore-legs of two kittens, killed in azotic gas, gave, after having been prepared, the same signs of electricity. A similar result was obtained, in other experiments, from the extract of hemlock administered to animals, whose electricity, it would therefore appear, or rather the capacity of the parts in which it is contained, is not diminished by poisons. Several frogs, exposed to the exhalation of corrupted flesh, displayed, after their death, signs of electricity, which were not, however, of a very powerful nature.

M. Moscati, one of the most celebrated naturalists of the present age, is the author of two experiments highly creditable to his talents and genius. Several frogs which had been deprived of life in the vacuum of Boyle, were subjected to an experiment, the result of which was the production of small movements, following each other in rapid succession, but obtained with some diffi-

difficulty. On this occasion, there was an extravasation of blood in the cellular membrane of the muscles, which tinged the flesh of a deep red. The blood, being a conductor of electricity, had dispersed in this case a portion of it, at the expence of the nerves by which the electric fluid was enabled to reach the muscular fibre. When this experiment was repeated on prepared frogs, there not being any extravasation of blood, the electricity ceased to be impeded or diminished. Several analogous experiments were made by M. Valli, and published in his work entitled, "Dissertation on the blood, considered both in its healthy and diseased state."

By the following experiment he proved that, without augmenting the degree of electricity, its velocity can be increased. He took a prepared frog, against which he directed a given torrent of electricity, by the means of a chain which touched the nerves of the animal. The frog, which at the beginning displayed convulsive movements, afterwards remained motionless for some time. On removing the conductor to an inconsiderable distance, the motions of the frog again took place; but shortly after, the animal fell into its former inert state. The current of the electricity having been afterwards accelerated by the approximation of an insulated conductor to the muscles of the frog, the movements were instantly

instantly displayed. On their subsiding, M. Valli established a communication between himself and the conductor; and the result was, that the movements were immediately excited. The inference he drew was, that the electricity is constantly the same, however the mode of its application may be varied. He observes, however, that the same thing does not invariably happen in operating on an animal in the full enjoyment of life, and in which there reside causes, capable either of retarding or accelerating the motion of the electric fluid. He therefore deems it of importance to seek these causes, more particularly in the different modifications of the sensation of the nerves, in the different proportions of their cortical and medullary substances, and perhaps also, in another nervous principle blended with the electric fluid, to which it is more or less united, according to the circumstances.

There are, he observes, still many researches to make on this subject, many obscurities to clear up, many errors to destroy, and many explanations to give. The demonstration of the existence of electricity in the animal machine, is a great step towards the advancement of science, and will tend to explain many phenomena which would otherwise have been left obscure. It is known, for instance, that men and animals live for a long time without having their blood refreshed

freshed by new chyle of a benign quality. If the blood were the source from whence the principle which animates all the parts of the machine is drawn, and if without it there could be neither motion nor operation in the system, life could not, at so great an expence of that fluid, be of any long duration. The mystery is now unveiled; the animal which does not receive aliments, attracts to itself, and draws, as well from the earth as from the atmosphere, that precious and necessary principle, the electric fluid.

It having been suggested to M. Valli, that, for the purpose of deciding whether the nervous and electric fluids are in reality one and the same, it was necessary to have recourse to the electrometer, he fell on the following expedient. Being at the moment unprovided with an electrometer sufficiently delicate for his experiment, he prepared fourteen frogs, the crural nerves of which he united in a single coating. Having put this battery in order, and established the communication by the means of an exciting arc between the nerves and the muscles, he excited the electricity they contained, and consequently produced the shocks. At the moment of the discharge, two very small pieces of straw, in some measure separated from each other, and nearly touching the apparatus, were instantly brought into contact. The result was consequently the same as would

would have been obtained by an electrometer. M. Valli afterwards repeated the experiment with that instrument, and obtained very sensible signs of electricity, thus demonstrating the identity of the fluids in question.

In a letter read before the late French Academy of Sciences, he acknowledges the error into which he had fallen, when he observed that it was necessary to apply a coating to the tunics of the nerves, to give a free passage to the electric fluid, seeing that the coating should, according to every probability, be considered merely as a condenser of the electricity, the movement being alike obtained, whether the nerve be coated, or the muscle itself.

The different metals, when employed as coatings, or as exciting arcs, present singular phenomena. Thus, with silver and gold, the animal gives but feeble tokens of vitality, or denies them altogether. This was clearly demonstrated in the experiments which M. Valli made in the presence of the commissioners of the French Academy of Sciences. He is of opinion that, by repeated trials made with the different metals, as well as with their mixtures and alloys, it would be possible to obtain such relations as would discover the hitherto unknown laws of that powerful agent of Nature, the electric fluid.

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Being persuaded that this agent may be subdued, and made to circulate, by the means of a simple coating of the muscle, he conceived the idea of obtaining the same result, without depriving the flesh of its integuments. The experiments he made on this subject did not constantly succeed, unless when two coatings were applied.

After the reasons he had already given and the arguments he had employed, to prove that the movements which are excited by the artificial means described by GALVANI, differ from those produced voluntarily by the animal, and that these two descriptions of movements are essentially different in the mode of their production, he relates a few facts and experiments, to confirm the doctrine he had established on that head. He afterwards relates the result of a small number of experiments he had made with the different poisons and gases, on frogs, mice, rats, and tortoises; in the prosecution of which experiments he was obliged to allow intervals of several minutes, not merely to give repose to the animal, so as to enable it to display new signs of electricity, but also to leave a sufficient space of time for the re-establishment of the equilibrium; a condition essential to the discharge of the electric fluid. Entertaining a suspicion that this destruc-

destruction of the equilibrium might have been produced by the medium of the nerves, which, agreeably to his hypothesis, by their pressure incessantly draw the electric fluid from the internal surface of the muscle, he contrived several experiments, on which it is unnecessary to dwell in this place, as M. VALLI acknowledges that, to be enabled to bestow on them a sufficient degree of credit, it would be necessary to repeat them. It will not, however, be amiss to observe, that this property of the nerves, by which the electric fluid is conjectured by him to be expressed from the muscles and conveyed to the brain, is regarded by M. VALLI as essential to the animal economy. He considers it to be necessary, not only to the voluntary motions, but also to the operations of the intellectual faculties, and to the sensible affections.

M. VICQ. D'AZYR, member of the late French Academy of Sciences, having proposed to M. VALLI the two following questions, namely, whether the blood-vessels are conductors of electricity? and whether movements could be excited by their medium, provided they were to be coated instead of the nerves? the latter replied by an observation which he had already made, that however the blood-vessels may be, as they assuredly are, conductors of electricity, the nerves alone are, in consequence of the mode in which they

they are disposed, capable of exciting muscular movements. This opinion, which he pronounces decidedly, is supported by no less than nineteen experiments.

Unquestionably, he observes, the arteries and veins are conductors of electricity, but less so than the nerves, which deprive them of a portion of their electricity, as is demonstrated by the second of the above-cited experiments. In support of this doctrine it should be observed, that it is impossible to obtain any movement, if the vessels be distributed in a direct way in the muscles, without communicating with the nerves. It is the same with the tendons, notwithstanding they are conductors; as are likewise the bones, but only when they are covered with their periostium. The membranes also are endued with a conducting quality, but are not productive of movements, unless when they communicate with the nerves.

It having been observed that the nerves, although dry, gave out by friction tokens of electricity, M. Valli endeavoured to ascertain whether, in this dessicated state, they could be rendered conductors of the electric fluid, and excite movements. He found this not to be the case. He was enabled to ascertain, by a series of experiments made on fowls, that ligatures applied to the nerves, at a certain

tain distance from the muscles, do not prevent the movements of the latter. He agrees that the result of these experiments is well calculated to overturn the theory he had imagined, relative to the identity of the nervous and electrical fluids.

Having drowned several pullets, and afterwards, when they gave no longer any sign of life, which seemed to be utterly extinguished, endeavoured to excite their electricity, movements were produced in a part of them, by the application of the exciting arc, while the others did not give out any signs of electricity. In repeating this experiment on six pullets which had been drowned, as in the former instance, the whole of them, on applying the are, were violently convulsed, and continued in that state for nearly an hour. The brain and wings of other pullets, purposely drowned, having been laid bare and armed, to give a more extensive scope to the experiment, violent convulsions were produced; but the animals were not, as might have been expected, restored to life. The same experiment, made on two small rabbits, was followed by the same consequences.

M. Valli having obtained the most decisive proof that animal electricity, when re-excited in drowned animals, has sometimes put in action the springs of the animal economy, to such a

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degree as to re-kindle a life which appeared to have been altogether extinguished, made several attempts to ascertain whether a similar phenomenon could be brought about in every description of asphyxia. He accordingly exposed several pullets, placed under glasses, to the action of the different gases, such as hydrogen, the nitrous gas, and azote. All these animals remained dead, notwithstanding the repeated efforts he made to recal them to life. The shocks which he obtained by the ordinary galvanic process, were invariably very weak, and succeeded each other at pretty long intervals. He concluded from hence, that the destruction of the equilibrium of the electric fluid, by which the discharges and movements are occasioned, depends on the principle of life, as it is more or less affected and weakened.

His first experiments not having appeared to M. Valli sufficiently conclusive, he made several others on frogs, which, generally speaking, resisted more powerfully the effects of mephitism than the other animals which had been the subject of his trials. He observed that the nitrous gas is more injurious to their temperament than the hydrogen gas; and noticed also, that the irritability of the muscular fibre, as well as the vital principle, appear to be preserved after death. The heart, removed from the body of the

the animal, and thrown into the hydrogen gas, palpitated with the same energy as in the body. When brought in contact with the nitrous gas, it continued to palpitate for some time. Four of these frogs offered a singular phenomenon. On the first application of the exciting arc, they became violently agitated; but after three or four shocks, became perfectly motionless. Having been left for some time in a state of repose, every effort which was afterwards made to excite them, proved ineffectual, notwithstanding it generally happens, that in animals of every description, and consequently in frogs, the movements cease gradually, as they become progressively weakened.

The muscles which were exposed to the action of the nitrous gas, suffered losses, which M. VALLI was enabled to calculate. To effect this, he separated the hinder extremities of a frog from each other, and placed one of them beneath a recipient filled with nitrous air, and the other beneath a glass filled with atmospherical air. At the expiration of an inconsiderable space of time, they were subjected to the experiment. The former of them displayed weaker movements than the other, and likewise lost its vitality much sooner. In one instance it had been left so long under the recipient, that it did not afford any evidence of electricity. The same experiment having been repeated with the

hydrogen gas, it was found that it operated on the muscular fibre with less activity than the nitrous gas.

The azote is equally injurious to frogs; the heart of which, it is true, still palpitates after their death, but the movements of which are enfeebled in a similar degree. M. VALLI was at first persuaded that the nitrous gas destroys the conducting faculty of the nerve, but was convinced of the contrary by subsequent experiments. The nerve, according to him, is in no case a conductor, when the electricity is weak; or, admitting it to be so, its conducting property is so imperfect as not to produce a sensible effect.

Another peculiarity of the nerves, which may tend to throw some light on the doctrine of animal electricity, is, that after the coating has remained for some time on any given part of a nerve, the movement ceases. By changing its position, and carrying it lower, the discharges and movements are renewed. Two circumstances, observes M. VALLI, ought here to be attended to:—in the first place, that the operator should hold the leg suspended in one of his hands; and secondly, that he should touch with the exciting arc, the coating only, and not the muscle.

The nervous fluid, which VALLI entitles *elec-*

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trical vehicle, and which is, in his opinion, secreted by the small arteries that proceed to the nerves, is, according to every probability, the fluid acted on by poisons, as well as by putrid mephitic miasmata. It is in this way that opium, on its being applied to a nerve, deprives the animal of the faculty of moving the limb in which that particular nerve is distributed. This also happens in the case of the plague. The impression made by miasmata on the nervous principle, is sometimes so powerful as to impair all the functions, which in particular cases are entirely suspended. The action of the miasma having however ceased, the springs of life are again put in action by the powers of Nature, and in a great measure by animal electricity, which, in seeking to establish an equilibrium, excites the irritability of the muscular fibre. From hence result the resuscitations which, after an apparent death, occasion so much surprize.

An experiment made by the above physiologist, not only demonstrated a double circulation of electricity, but also, that when the portions of the electric fluid circulating from different points meet in contact, and one of them has a greater degree of force than the other, the weaker is obliged to yield, and is entirely destroyed by the more powerful.

A very curious fact is related by M. VALLI,

 namely,

namely, that when, in the progress of his experiments, he was surrounded by several persons, the movements excited in the frogs were not so powerful as when he was alone, or with one or two individuals only. He adds, that he could not obtain, in living frogs, any signs of electricity, unless he laid bare either the muscles or the nerves. He next made several observations, which enabled him to ascertain how far his experiments were influenced by the will of the animal, and noticed the consequences which resulted from this volition on their part.

M. Valli having on a former occasion made several experiments, to determine the space of time during which certain animals can live without nourishment, repeated them, and drew the following conclusion, that, in a state of abstinence, the blood and humours still preserve their natural characteristics. The bodies of several dogs and cats, which had died at the end of an abstinence of thirty-nine days, were much longer in passing into a corrupted state than those of animals killed in their natural state. He noticed several particular facts, which are in direct opposition to the objection that has been made, that the blood and humours may be vitiated without being in a putrefactive state. He afterwards endeavoured to discover the means employed by Nature to resist the changes which result from long

long abstinences; but as this inquiry is not immediately connected with the subject in question, it is unnecessary to enter into a detail of the author's physiological and chemical explanations.

The nerves have, at each point, a principle dependent on life, which perishes in proportion to the muscular contractions. These contractions may be considered as so many electrical discharges. The experiments made by M. VALLI prove that this principle perishes gradually of itself; and that its destruction invariably commences at the upper part of the nerves. It is erroneous to suppose that the nerve becomes desiccated during the operation, and that its torpid state, and want of energy to conduct the electricity, are to be ascribed to that cause. By carrying from the upper to the lower part the coating applied to the nerves, trying them progressively at the smallest divisions of their lengths, or, in other words, by establishing at these almost imperceptible intervals, the communication between the coating and the nerve, M. VALLI constantly succeeded in ascertaining the precise point which was fitted for the experiment, and thus discovered the last remains of the vitality of the animals subjected to his experiments. It follows from hence, that this mode of existence of the nerves, which enables them to produce the muscular movements, that this *life of the nerves*, as it is

termed by VALLI, is more inherent at their extremities than at their origin, unless what he denominates, in common with other naturalists, the extremities of the nerves, should on the contrary be in reality their origin.

All the facts which have been cited, prove that the voluntary movements of the muscles are performed by a circuit of electricity, or electric battery; and that the other movements, those more especially which depend on the viscera, obey another law which has been already noticed. This is the reason why, when the nerves of the above organs are armed the exciting arc does not produce in them any sensible change. The heart of a dog, purposely killed for the experiment, did not palpitate, notwithstanding the eighth pair of nerves was armed at the time that the viscus was hot and reeking. The same trial was made on the diaphragmatic, intercostal, and great sympathetic nerves of a horse, with precisely the same result. A fore leg, the brachial plexus of which had been denudated, and enveloped in a small piece of tin-foil, did not become convulsed when the coating and flesh were touched with a silver spoon. A few gentle oscillations of the muscles near the shoulder were, however, perceptible.

It appears evident, that M. VALLI has adopted an inherent electricity in the different parts of the animal organization, but with this modifica-

tion,

tion, that, according to his theory, the interior of the muscles is negative, and the exterior positive. He accounts for this electrical state of the interior part by the action of a particular power residing in the nerves, the existence of which he seems ready to grant.

The following are the general results of several more recent experiments made by M. Valli.

1st, That a single metallic conductor suffices to produce convulsive movements in frogs that have been recently killed; and that the coating, whether applied to the muscle or to the nerve, is not an essential condition to bring about these movements. That scissars of a bad quality of steel were successfully emyloyed by him as a conductor; but that gold, silver, lead, copper, and tin, do not in general produce any effect.

2dly, That animal electricity passes through glass and sealing wax, when these substances are thoroughly heated.

3dly, That water made very warm, or in a boiling state, disperses the electricity in such a way as to destroy the phenomena which would otherwise result from it.

4thly, That excessive cold deprives this same water of the property of conducting the fluid in question.

5thly, That the prepared feet of dogs, cats, and rabbits, remain motionless when an individual forms a part of the chain.

6thly,

6thly, That the diaphragm of a dog having been plunged by M. VALLI in a vessel of water, in such a way as that the phrenic nerve, which had been previously armed, was made to reach the external part of the vessel, he was enabled to excite weak contractions in that muscle, by touching the coating with a coin of gold or silver, at the same time that he put one of the fingers of the hand which was disengaged into the water.

7thly, That a metallic thread, covered from one extremity to the other with sealing-wax, ceases to act as an exciting arc when the vitality of the frogs begins to be exhausted. This is, according to M. VALLI, a proof that the electricity passes along the surface of the conductors.

8thly, That the ligature of the nerve, near the muscle, prevents the progress of the animal electricity; and that a ligature made in this way opposes an equal resistance to artificial electricity.

9thly, That if a known quantity of the electric fluid be conveyed to the crural nerves of frogs, one of them tied at a small distance from the muscle, and the other without any ligature, the movements of the latter will be found to be more sensible than those of the former.

10thly, That when the artificial electricity is extremely weak, it excites the irritability of the muscles of the leg only, the nerve of which has not been tied, although contractions can be pro-

duced

duced in the other leg by the excitement of its own electricity. The experiment furnishes a method of calculating the power of animal electricity. If, for instance, five, six, or seven degrees of artificial electricity are not sufficient to produce the contractions, at the same time that they can be generated by exciting the native electricity, it may be said that the latter is stronger than the given quantity of five, six, or seven degrees, &c.

11thly, and lastly. That the excitement produced in the limbs of animals by the known method, instead of destroying their irritability, tends to give it an additional support. This fact renders the following experiment more perspicuous. Having prepared, observes M. VALLI, the wing of a fowl, or the paw of a cat or dog, I subjected it to the customary trial. At the expiration of half an hour, I armed the other wing of the fowl, or another paw of the cat or dog, and had recourse to my exciting arc. The latter wing, or paw, however, did not give any sign of electricity, while the parts which had been subjected in the first instance to the experiment, still continued in a convulsed and agitated state.

The foregoing experiments were made in London, from whence M. VALLI afterwards communicated the following facts to the Philomatic Society of Paris:

1st,

1st, That opium, applied to the extremity of the nerves, acts more powerfully than when it is applied to their origin.

2dly, That having subjected the diaphragms of four horses to a galvanic experiment, they remained motionless, at the same time that, when the trial was made on dogs, the contraction of that muscle constantly ensued.

3dly, That he could never succeed in producing contractile movements in the heart, stomach, intestines, or bladder, notwithstanding he armed the nerves of all these different parts.

And, lastly, that it required a charge of artificial electricity of an uncommon strength, to excite contractions in the wing of a fowl, the nerves of which were armed, and which had been previously steeped in oil, at the same time that the native electricity preserved nearly the whole of its original intensity.

In a communication made by FONTANA, on the subject of animal electricity, that celebrated naturalist gives the result of several experiments analogous to those of GALVANI and VOLTA. The following is an extract of the interesting paper:

" Relatively to the movement of the heart," observes FONTANA, " I have been enabled to ascertain that it is easy to accelerate its contractions, if it is in motion, and to put it in motion if it is in a state of repose. For this purpose, it suffices

fices to place it between two metals, zinc and antimony, for instance, in such a way as that a portion of this viscus may touch one of the metals, and the other portion the other. By establishing a communication between the two metals, by the means of a conductor, the phenomena I have pointed out above will be displayed, even when the heart is separated from the body, and cut in pieces. I have also succeeded in producing contractions in earth-worms, insects, and animals deprived of the brain and nerves. I shall publish very speedily a work on the new principle of muscular movement, discovered at Bologna by the learned Professor Galvani, and I trust that I shall be able to demonstrate incontrovertibly, that this principle is not in any degree connected with electricity, and that, whatever it may be, it neither brings about the contraction, nor re-produces the ordinary muscular motions in animals. Thus is this obscure principle reduced to a very fine phenomenon, the nature and uses of which still remain to be investigated."

These experiments were repeated at Pavia by M. Marsigli, in the presence of Professor Volta. The same results were obtained when zinc and antimony were employed; as was also the case when the heart was placed between silver and tin. When a portion of the heart of a fowl was placed on a bit of charcoal, which appears, by

by the experiments of VOLTA, to be preferable to the different metallic substances, and another portion laid on a piece of pasteboard covered with tinfoil, the heart contracted repeatedly, and became very powerfully convulsed.

Such is the general result of the experiments made by FONTANA. It is much to be regretted that he has not hitherto complied with the promise he made, to publish a work on muscular motion.

Several experiments, similar to those of FONTANA, were made about the same time, that is, at the commencement of 1793, by M. DE LA METHERIE, who remarks that charcoal is not so good a conductor of common electricity as metallic substances. This leads him to observe, that flesh is not so powerfully endued with the property of conducting electricity as charcoal; and he explains, in this way, how it is that a person who touches on the one hand the denudated nerves of a frog, and on the other muscles also laid bare, does not excite any movement in the animal. The same experiment, made with water, was attended by the same result. The following are the consequences which this physiologist draws from his experiments, taken collectively.

1st, In a prepared frog the electricity is very weak.

2dly,

2dly, It is more powerful at the instant the animal has been deprived of life; consequently it has a still greater intensity in the living animal; and from hence it follows, that it cannot be made to communicate from the nerves of a frog to the muscles, unless by the means of good conductors. Thus all the metals which are good conductors, however they may vary in the degree of their efficiency, establish this communication.

3dly, Plumbago and charcoal, although less efficacious conductors than metallic substances, are, notwithstanding, sufficiently so, to enable the electricity of the nerve of a frog to find its way into the muscles.

4thly, Animal substances are not sufficiently powerful conductors to produce the same effect, seeing that a person who touches at the same time the denudated nerves and muscles of a frog, cannot establish the communication.

5thly, Water is in the same predicament with animal substances, and is equally unfit to establish the communication. Thus, when a prepared frog is plunged in water, with the customary apparatus and the metallic coatings, the exciting arc produces movements in the animal; for this reason, that the water is no more capable of conducting this feeble electricity, than the atmospherical air, when perfectly dry, is capable of conducting the ordinary electricity, notwith-

standing

standing the latter, in its humid state, conducts it perfectly well. It is true, that the experiment succeeds when the prepared frog and the metallic coatings are placed on a table without being insulated; but this happens because the table is not in the present instance a sufficiently good conductor, and is conseqüently in the same predicament with the water.

These experiments appear to M. DE LA METHERIE to obviate the objections which have been made against the identity of the electric fluid, and the fluid which produces movements in the animals prepared as above. From hence he thinks himself justified in the conclusion, that the animal electric fluid does not differ from the common electric fluid, unless in that particular, that, in consequence of its being much weaker, it cannot circulate without the help of excellent conductors.

Professor TOURDES, of Strasburgh, communicated to Professor VOLTA the result of an experiment, which appeared to him to resolve one of the most disputed points of physiology, that of the vitality of the blood. This liquid, he observes, deprived of the serum, lymph, &c. reduced to the fibrous part, and subjected to the galvanic, or rather electric apparatus (for he considers the identity of the galvanic and electric fluids to have been incontestably established by the

the Professor's researches), at the temperature of about thirty degrees of REAUMUR (about an hundred of FAHRENHEIT), exhibited a trembling oscillation and palpitation analogous to those experienced by the flesh of animals newly killed; *a double motion of contraction and dilatation*, sensible to the eye by the medium of a magnifying glass; and a characteristic mark of the vital force peculiar to the muscles, cellular tissue, &c.

A mind possessing the least sensibility, recoils at the distressing necessity of inflicting a painful death on so many animals; on which account, when a physiological fact has been once ascertained, I have avoided any repetition of the experiment, particularly when in the operation the animal is subjected to many tortures. Custom, perhaps, more than Nature, occasions us to consign so many to purposes of luxury alone. Through the gratification of an idle curiosity, to destine many to agonizing operations, is unwarrantable cruelty, and particularly when the ascertainment of the fact in question is not adequate to the sacrifice. Every feeling mind must experience a sensation of horror at the experiment of SPALLANZANI, in destroying with hot wires the eyes of a poor bat, merely for the indulgence of an idle whim. A series of experi-

ments on animals is only justifiable, when the result may prove of advantage to our fellow-creatures; then, and then alone, our feelings are balanced by the interest of humanity.

CHAP.

CHAP. IV.

Galvanic experiments of M. Berlinghieri, *of Pisa—Singular experiment of* M. Volta *with metallic substances—Experiments made on amputated limbs—New facts relative to galvanism—Confirmation of the system of* Galvani*—Letters of* M. Vassali-Eandi *on galvanism—Premiums proposed for dissertations relating to galvanism.*

TOWARDS the close of the year 1792, M. Berlinghieri, of Pisa, in a letter to M. de la Metherie, announced that he had been employed, in concert with M. Pignotti and his brother, in making a series of galvanic experiments, the details of several of which he transmitted. They are to the following effect:

1st, It was observed that, to produce contractile movements in an animal, it was sufficient to establish the communication between the bent metallic rod and the crural nerves, above the point where they are inserted in the thighs.

2dly, That it is of no importance whether the bent rod of metal is forced into the spinal marrow, the brain, or any other part, it being

simply necessary to remove that portion of the spine which is between the origin of the crural nerves and their insertion in the pelvis, and to take out the abdominal viscera. It is even sufficient, to produce the contractions, that one of the fore feet of the frog should be tied with a piece of iron wire, and a communication established between the wire and the crural nerves or thighs.

3dly, That having cut off the head of a frog, taken out the abdominal viscera, and laid bare the crural nerves, without dissecting them, and without removing the spine, as is usually done, on piercing any part of the trunk whatever, with a bent rod of iron, no contractions will be produced when a communication is established between the rod and the thighs. But if the rod be touched with an extremity of the exciting arc, and the crural nerves with the other extremity at the same moment, very powerful contractions will be produced.

4thly, A singular experiment made by M. Volta, which leads to the subsequent experiments of M. Berlinghieri, is here cited. It is as follows: Take a crown-piece, place it on your tongue, and examine the sensation it produces. Take a piece of tin-foil, and do the same. Next, put a crown-piece under the tongue, over which lay the piece of tin-foil, each of these substances touching the tongue, but without being any

where

where in contact with each other. Now, bring the part of the tin-foil which projects from the mouth in contact with the crown-piece. The moment it touches it, and so long as it continues in contact, you will feel on the tongue a very singular and remarkable sensation *.

The above naturalists were desirous of ascertaining, whether there is any analogy between the above phenomena and those displayed by a prepared frog subjected to experiment. For this purpose, after having cut off the head of a frog, and taken out the whole of the abdominal viscera, without dividing the spine, they introduced a bit of tin-foil between the spine and the crural nerves, contriving that the latter should lie on the tin-foil. They now took a silver needle, and applied it in such a way to the nerves, as that they should be between the silver and the tin, without the foil being any where touched by the needle. While the apparatus was in this posi-

* This experiment, and others which will be noticed hereafter, prove that the experiment made by SULTZER did not lead to the discovery of galvanism; and that the naturalists who have been employed in making researches on that science, were perfectly well acquainted with the above experiment, which the greater part of them did not think it necessary to mention, for the reasons given in the first chapter of this work.

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tion, no contractions were to be noticed in the frog; but as soon as the needle was brought in contact with the tin-foil, in whatever way this was contrived, very powerful contractions were instantly perceived in the muscles of the animal. This experiment was repeated a considerable number of times, and invariably succeeded when it was cautiously made. It appeared to the naturalists in question, to present a striking analogy between the experiments of GALVANI and the above cited experiment of VOLTA.

In concluding his letter, BERLINGHIERI observes, that the phenomena in question are not only peculiar and appropriate to the frog, but that GALVANI had noticed them in experimenting on animals with hot blood. The latter, however, he observes, require a peculiar process, which is as follows: After having dissected the crural nerve, or any other considerable nerve whatever, and cut it at a certain height, to separate it from its superior part, it should be coated by surrounding it with a piece of tin-foil at its summit, and the communication then made in the usual way, by touching the coating with one of the extremities of the exciting arc, and the muscles in which the nerve is distributed with the other extremity. This experiment has succeeded perfectly well on animals, and even on man. In the hospital of St. Ursula, at Bologna, similar

similar trials were very successfully made on the amputated arms and legs of several of the patients, whose cases had rendered the operation necessary.

It may not be improper to digress in this place, by observing that Mr. LARREY, late surgeon-general to the French army of Egypt, in a letter addressed to the Philomatic Society of Paris in the year 1793, states, that having been obliged to amputate the thigh of a man, whose leg had been fractured and lacerated by the wheel of a carriage passing over it, he was led to repeat the experiments of GALVANI and VALLI. Having, accordingly, dissected the popliteal nerve, the trunk of which he insulated to its smallest ramifications, he inclosed the trunk in a piece of sheet-lead, after having denudated the trunks of the internal and external *gastrocnemii* muscles. He now took a pile of silver in each of his hands, and, touching with one of them the coating of lead, brought the other hand in contact with the muscles, which became so violently convulsed as to affect, by their contractile and spasmodic motions, both the leg and foot. This experiment was repeated by Dr. STARCK with a similar result. It is observed by each of these physiologists, that pieces of steel or iron did not produce any very striking effect; but that when a bent silver probe was employed as a conductor, not-

withstanding the amputated limb was at the time nearly cold, the effect was very sensibly increased.

To return to M. BERLINGHIERI. He did not confine himself to the experiments contained in the letter which has just been analysed, but, in a communication addressed to the Philomatic Society of Paris, brought forward new evidences of the identity of the animal fluid and electricity. He observes,

1st, That naturalists had been led into an error, when they supposed that it required a heterogeneity in the metals employed for the coating and for the exciting arcs; since he had frequently obtained a decisive result when he employed iron as a conductor, as was also frequently the case when he employed iron and steel conjointly.

2dly, That having dissected the crural nerves of a frog from one extremity to the other, and cut them transversely in the middle part, he had separated them to the distance of about an inch, and having laid them on a surface of glass, had filled up the interstice between them with a bar of silver. By the application of the exciting arc very remarkable effects were now produced; but a piece of sealing-wax having been substituted to the bar of silver, destroyed the communication, and put an end to the movements and contractions.

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These two latter experiments were repeated in Paris by the commissaries of the Philomatic Society, by whom they were found to be perfectly correct. They noticed particularly, that the coatings and exciting arcs of homogeneous metals, such as tin, plummers' lead, iron, &c. which they employed, excited very sensible movements in the frogs immediately after they had been prepared for the experiment. When the above condition is observed, the effects cease very speedily; but re-commence as soon as the metal of one of the two coatings, or that of the exciting arc, is changed.

The commissaries in question, in repeating several of the experiments of M. Berlinghieri, noticed the following facts, which did not appear to them to have been hitherto observed:

1st, The phenomena remarked in the experiments already before the public, continue to take place *in vacuo*, where they even subsist after the admission of the air.

2dly, It was observed that living bodies are not sufficiently powerful conductors to determine the passage of the fluid. Thus, a person who presents his fingers, instead of the exciting arcs and coatings, does not produce any movement or contraction in the animal; but if he arms either of his hands with the smallest metallic conductor possible, for instance, with the point

point of a needle, he in that case excites very singular convulsive movements.

3dly, The effects on cold-blooded animals appeared still more remarkable in oil than in water, and remained noticeable for a much longer time.

4thly, A piece of metal of any description, whatever may be its conducting quality, if it be covered with a superficies of mercury, loses its primitive quality, and merely becomes a conductor of the fluid in the same way with any other piece of metal covered with mercury in the same manner.

5thly, A very thin plate of glass, not more than the fifteenth part of a line in thickness, suffices to prevent the passage of the fluid, and altogether to impede its effects.

6thly, Artificial electricity, by a direct application continued for some time, deprives the animal of the faculty excited by the metallic contact. The discharge of a small Leyden phial produces the same effect.

7thly, An animal placed on a conductor charged with artificial electricity, whether positive or negative, presents the same phenomena when subjected to the preceding experiments.

8thly, An animal, insulated and plunged into an electrical atmosphere, that is, placed at the distance of two feet from a conducting body which is electrified, becomes violently convulsed as often as the observer, by drawing a spark,

deprives

deprives the conductor of the electricity it has received.

It has been already noticed that BERLINGHIERI, in one of the letters he addressed to the Philomatic Society, communicated a particular experiment of VOLTA, observing, that he had found a complete analogy between that experiment and those of GALVANI, on arming the nerves of the spine of a frog in the same manner; and, lastly, that the movements, which did not take place until the moment of contact, pointed out the sensation of the animal. In repeating the above experiment, the commissaries of the society made an additional observation, namely, that the taste was very perceptible when two different metals, each of them applied to one of the surfaces of the tongue, were brought in contact. This taste, which is slightly acid, and occasionally saline, varies sensibly when the metals are changed. In this case it is considerably augmented, more especially when one of the two pieces of metal has been rubbed over with mercury. The taste is then considerably stronger, and occasions an abundant discharge of saliva. Zinc and silver also produce a very powerful effect.

In a memoir published by CORTAMBERT, member of the Medical Society of Emulation of Paris, the author endeavours to demonstrate that the expla-

explanation of animal electricity given by GALVANI, however ingenious it may be, cannot maintain its ground against a multitude of objections which have been made to it, seeing that an external force and an internal force cannot be admitted in the nerves, so long as either of these force is not insulated from the other. There is not, he observes, in the animal machine, any mean by which one part of the nerve can be charged at the expence of the other, by the establishment of a positive electricity and a negative electricity. Metallic substances cannot be considered as condensers, since metals, far from possessing that property, are excellent conductors of electricity; and, even should these difficulties be passed over in silence, it may be asked, where the power resides which performs during life the function of a coating? And by what conducting art this power is enabled to establish a correspondence between the parts electrified in *plus*, and those electrified in *minus*? On the other hand, before an attempt was made to point out the laws which the nervous fluid follows in its action, it ought to have been incontrovertibly proved, that it is the same with the electric fluid. The following are the most conclusive experiments in favour of that opinion; but as the author of them, M. VALLI, observes, they stand in need of frequent repetitions to be confirmed.

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'The crural nerves of fourteen frogs were united in a single coating, and the contractions having been produced in the customary manner, two bits of straw, placed very near this apparatus, were instantly brought in contact with each other. In a similar experiment the ball of the electrometer was sensibly attracted; and on another occasion, the hairs of a mouse were made to stand erect. To this theory, the following objections may, however, be made:

1st, That a person who touches the coating, does not produce, in the animal, the discharge of electricity he would nevertheless produce on touching the electrical machine.

2dly, That these phenomena take place in a similar way in animals which are not insulated.

3dly, That the electric fluid, as has been observed by HALLER, cannot be retained in the nerves, and ought of necessity to be distributed in every other part, supposing even that the nerves are the best conductors of electricity.

4thly, That a ligature made in a nerve impedes the circulation of the nervous fluid.

5thly, That the conducting property, as it would appear, is not the same in the electricity of the nerves and in common electricity. For instance, charcoal, which is a bad conductor of the latter, excites more powerful contractions than those produced by metallic substances.

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These facts, combined with others which it is unnecessary to detail in this place, occasion doubts at the least, whether the nervous fluid be the same with the electrical fluid, retained by, and acting in the substance of the nerves. It would however appear, that if the nature of this fluid has not as yet been demonstrated, its existence ought no longer to be doubted; and that the discovery of GALVANI possesses the advantage of having given a reality to a system.

Such appears to be the decided opinion of CORTAMBERT: GAILLARD, another member of the Medical Society of Emulation of Paris, likewise made several ingenious galvanic experiments. In repeating those of the Italian naturalists, he observed that the different metals do not act with the same efficacy on the animal economy; and that in proportion as this difference, which may be stiled *galvanic capacity*, was great, the more powerful was their action when combined. In conformity to this ratio, he classed those with which he operated, and arranged them in the following order: Zinc, tin, lead, antimony, iron, bismuth, copper, mercury, and silver. He afterwards endeavoured to ascertain the degree in which the purity of the metals, the temperature, and nature of the medium employed, and finally, the excitability of the animal, influence experiments of this nature. He concluded by attempt-

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ing to apply to the operation of galvanism a considerable number of vegetable and mineral substances. Those which contained any portions of metal succeeded in a greater or less degree, according to the nature and quantity of the latter. The effects of charcoal alone were however particularly striking, although its different degrees of purity were productive of very sensible variations.

At the time when the above researches were made, the following letter was addressed to M. DE LA METHERIE, by M. VASSALLI-EANDI, an Italian naturalist. It is given in the author's own words:

"You ask my opinion relative to galvanism, that is, relative to the cause of the muscular contractions which are excited when the nerves and muscles of a living animal, or of an animal recently dead, are touched at the same time by a substance possessing the property of conducting the electric fluid.

"Your inquiry is directed to the nature of the agent which produces the commotions. Whether it is the electric fluid, excited or put in motion by the contact or slight friction of metals, or of other heterogeneous bodies? Whether it is the electricity peculiar to the animal, communicated by the conducting substance from one part of an organized body to another? Or lastly, whether

it

it is a fluid different from electricity? These are questions which, in my opinion, have not as yet been resolved by any truly decisive experiment, notwithstanding so much has been written and said on this subject.

"The memoir of Dr. GALVANI, whose name has acquired so just a celebrity, came to my hand at a very early period; and after I had repeated his experiments successfully, and added a few of my own, I observed that it was necessary to wait for still more demonstrative proofs, to be enabled to establish a solid theory. I am still disposed to persevere in the same opinion. Indeed, after having seen the delicate and ingenious experiments of Professor VOLTA, a considerable number of which I have repeated with the same results, I have been almost inclined to think with him, that the muscular contractions are excited by the electricity of the metals, or of the heterogeneous bodies which are employed as conductors; and that consequently the existence of animal electricity cannot be perceived in the phenomena noticed by GALVANI, which, in conformity to this theory, prove nothing more than that animals are electrometers, still more sensible to the smallest degree of electricity than any other electrometers.

"The experiments I made with my electrometer with gold bands, appear to confirm this opinion,

opinion, seeing that the smallest atoms of sealing-wax, of rasped chocolate, &c. laid on that instrument, bestowed on it a sensible electricity, which was invariably produced by the almost insensible friction that takes place, when a small stick of sealing-wax is employed, however lightly and delicately the operation may be performed. It is not difficult to be persuaded from hence, that animals are electrometers, sensible to the electricity excited by the contact or gentle friction of heterogeneous bodies. But if, as I stated to Professor VOLTA, the muscular contractions are caused by the electricity excited in the metals by contact, how does it happen that they do not take place when the metal which touches the nerve or muscle is rubbed by a non-conducting body? The electricity is notwithstanding very strong in this case; and still the contractions are not produced. It has however been ascertained, that a more powerful artificial electricity, whether positive or negative, excites contractions.

"I might add several other reflections on this subject; but I do not propose in this place to examine the question. I shall proceed accordingly to the theory of GALVANI, improved by his nephew ALDINI. A short time ago, the latter stated to me, that his uncle was prepared to reply to all the objections brought forward by VOLTA.

 I trust

I trust that this work will be completed, and that the philosophical sciences will, on this head, be recompensed by ALDINI, for the loss they have sustained by the death of the illustrious GALVANI.

"According to the theory of these two learned professors, the animal body is a description of Leyden phial, or magic battery; in one part of which there is an excess of electricity, and in the other a deficiency. The conducting body communicates the fluid of the part where it is abundant, to the part where it is defective; and in this passage of the electricity, the muscular contractions are obtained in the same way as the discharges are produced by the Leyden phial or magic batteries. As the conducting bodies of the electricity are the sole agents in the discharge of the Leyden phial, so the same bodies alone serve likewise to excite the muscular contractions. Now as the Leyden phial, after a few discharges, no longer gives out any signs of electricity, in the same way the animal, after having been made the subject of several contractions, remains motionless. Nature avails herself of the passage of the electricity to bring about the different movements, and perhaps even for the purpose of perception.

"This simple theory, notwithstanding it is supported by the greatest analogy, and by a variety

riety of electrical phenomena, is still deficient in evidence; for if the animal body be compared to a Leyden phial, when, in the case of the latter a conducting arc is brought near to the ball which communicates with the inner part of the phial, while the other extremity of the arc touches the outer part, light bodies are seen to dart from the ball to the arc. The same phenomenon ought to take place in the animal Leyden phial, if I may be allowed to employ such an expression. However, although Dr. Valli, Professor Eandi, my uncle, and several other persons, have asserted that they had observed electrical movements in the experiment of Galvani, as it is one of those which require the utmost delicacy, and seeing that the observer may be deceived by the slightest breath acting on the light corpuscles, I shall here frankly avow, that I repeated this experiment several times, changing the apparatus, and employing bits of gold-leaf and other very light substances, without being enabled to ascertain that any electric movements ensued. What conclusion is to be drawn from hence? Is it to be said, that the fluid which produces the muscular contractions, is neither metallic electricity, nor animal electricity, but another essentially different fluid, of the nature of which we are ignorant? I shall not undertake to hazard such a proposition; and as I am not provided

 with

with the *experimentum crucis* of BACON to remove my doubts, I cannot, consequently, come to any immediate decision on this subject.

"Nevertheless, were I to be called on to give an opinion, I should state my persuasion, that the muscular contractions are produced by the movement of animal electricity, directed by the conducting bodies of natural electricity: since, without bringing forward, in support of this opinion, the innumerable facts published by Doctors GARDINI, BERTHOLON, COTUGNO, GALVANI, ALDINI, VALLI, EANDI, GIULIO, ROSCI, VOLTA, &c. I shall simply observe that, in nature, each body, in changing its chemical state, changes also the capacity by which it is enabled to contain the electric fluid. That it likewise frequently changes its property, so far at least as electricity is concerned, is a fact which is particularly noticeable in the metallic oxydes. Now, as there can be no doubt but that the air in respiration, and the aliments in digestion, change their chemical state, they must necessarily change likewise their capacity for the electric fluid. READ has demonstrated, that air, in respiring, loses its natural electricity; and it has been proved by me, that urine gives out a negative electricity. I have repeatedly shewn to Doctors GERBI, and GARETTI, as well as to the students in medicine and surgery, that blood, drawn from the

the veins, subjected to my electro-metrical apparatus, furnishes a positive electricity. Consequently, the natural electricity of the air, and of the aliments, abounds in certain parts of the body, at the same time that in the same body there are other parts which do not contain a quantity proportioned to their capacity. The electric shocks given by the torpedo, the gymnotus electricus, eels, cats, rats, &c. confirm my assertion. The precise anatomy of animals, will explain to us the reason of this phenomenon, in the same way as the anatomy of the torpedo, communicated to me by SPALLANZANI, explains the mode in which that animal gives the shocks.

" If to this combination of facts it be added, that the nerves of the torpedo press out and extract the electricity contained in the muscles, as has been experimentally proved, the theory of GALVANI becomes in a very great degree probable; seeing that it may with every propriety be observed, that if an electrical movement cannot be noticed, in bringing the conductor near to the muscle, or rather to the nerve, it is because a slight compression is necessary to facilitate the passage of the animal electric fluid, as is observed in the torpedo, which does not give any shock, unless its muscles be slightly compressed."

By this letter of VASSALLI-EANDI, it would appear to be his persuasion, that there are in the

human body, parts which are electrified positively, and other parts which are electrified negatively. The following communication on animal electricity, addressed by him to Professor Buvina, of Turin, tends to confirm this opinion.

"The electrical phenomenon which you observed in my electrometer, placed on the back of a diseased animal at the moment of its being attacked by a fit of shivering, appears to me to be a necessary consequence of the general theory of electricity, and of the modifications it experiences in the animal economy. The following is the mode in which it appears to me: I have proved, in my letter on the origin of animal electricity, that man, in a healthy state, in common with all other animals, has parts positively electric, while other parts are negatively so.

"It would appear that, in the animal, the negative part, that of the excretions, is not so strong as the positive part, that of the blood. But if the natural boundaries of electricity in the body be destroyed by a change in the animal economy, on account of the tendency of the former to bring itself into equilibrium, it ought to escape and to manifest itself at the precise moment of the destruction of its boundaries; that is, when the virus changes the internal parts, as is denoted by the febrile paroxysm. Fear, and other violent passions, in producing changes in the

the animal economy, ought likewise to be attended by the same effect. You have thus seen the strings of my electrometer, placed on the back of an animal, separate from each other, either during the fits of shivering occasioned by a contagious disease, or during those produced by fear; and you must have noticed, that the same theory likewise explains the defect of electricity which you observed in diseased cats. I am persuaded, that this defectiveness will in no case exist until the disease has continued for several days, and until a complete derangement of the animal economy has taken place. When I had concluded my electrical experiments on water and ice, I repeated them on several liquids, animals, and vegetables, as well as on different preparations of water; and shall here notice, as a particular result, that urine and animal humours exhibited the greatest degree of electric difference. You will thus perceive that my opinion is supported by facts. As I have found, however, that the blood of those labouring under intermittent fever is still positively electric, it might be useful to ascertain in what diseases, and in what particular stage of these diseases, it loses its electricity. It appears to me that the electrometer may be employed to distinguish violent diseases, and be converted, if I may be allowed the expression, into a vitalitometer. A great

 diversity

diversity of experiments are, however, still needed, to attain a similar point of perfection in the science of electricity. The discovery of the electricity of the torpedo appears to me to be truly astonishing. That of COTUGNO, who received an electric shock from a mouse, in the dissection of which he was employed; and that of TONSO, who in the same way received a shock from a cat, added to my electrical experiments on rats, appear to be conclusive. The immensity of Nature still presents, however, materials for new researches; and at the present moment even, now that I have made the discovery of the contrary electricities of the blood and excretions, I can perceive that much still remains to be done, to be enabled to form a due appreciation of the opinions of GALDINI, BERTHOLON, TRESSAN, and CARLIEU, on animal electricity. You have pursued the best route, that of interrogating Nature by experiments. Persevere in doing this, and you will enjoy the satisfaction of having enlarged the boundaries of science."

It having been objected to M. VASSALLI-EANDI, that animals, although dead, were still sensible to galvanic experiments, he demonstrated that animals, killed by phosphorus taken internally, or in the vacuum of a pneumatic machine, cease to be acted on by galvanism. He was thus confirmed in his conclusion, that when the animal

mal organization is deranged to a certain point, the diseased subject loses its portion of natural electricity.

Having thus far detailed the different opinions for and against the theory of GALVANI, as well as the experiments of which these opinions are founded, it may not be amiss to close the present chapter by an account of the encouragements which were held out to scientific men, shortly after the discovery of galvanism, for their researches on this very curious snd important subject.

The phenomena of galvanism were scarcely known and circulated in the learned world, when several literary societies proposed premiums for the encouragement of the physiologists who should cultivate successfully this new acquisition made to the Sciences. In 1793, the Society of Sciences Junoblowiskiana proposed, as the subject of a premium in philosophy, to be bestowed in 1795, the experiments of GALVANI, VALLI, VOLTA, and others. The competitors were requested to point out the new facts to which these experiments had led; to shew how they could be classed in a useful way; and how they could be explained in conformity to the existing state of philosophical knowledge.

About the same time, the Medical Society of Edinburgh made this physiological question the subject

subject of a premium which that society distributes annually; and gave the award in favour of Professor CREVE, of Mentz, who, as will hereafter be seen, substitutes in his memoir what may be considered as a glaring impropriety, the term metallic irritation, *irritamentum metallorum*, to that of animal electricity employed by GALVANI.

In the course of the above year, the Philomatic Society of Paris, received from an individual, who thought proper to conceal his name, a medal of the value of a hundred livres, about four pounds sterling, to be bestowed on him who should, on or before the first of January 1794, explain in the most satisfactory manner the following propositions:

1st, " To demonstrate, in a precise way, the analogy, or the differences, between electricity and the animal fluid, the existence of which has been ascertained by Professor GALVANI and Dr. VALLI.

2dly, " To determine the functions which this fluid performs in the animal economy; how far its different states may influence the health of an individual; and what are the means of restoring to it the equilibrium, the proportion, and the movement which it ought to preserve.

It would appear, either that the competition for this premium did not ensue, or that the society was not satisfied with the replies of the compe-

competitors, since there is no question in the documents it has since published, of the premium having been awarded to any one. It must at the same time be agreed, that it was of too inconsiderable a value, so as to be not even equivalent to the expences and researches which were to be made, to enable the inquirer to discuss the subject proposed, and to make the necessary experiments. That it is not interest which, in competitions for premiums and rewards, influences those who engage in the task, is what I can readily conceive. But, on the other hand, it is essential that the competitors, in entering on their labours, should be certain to find at the least, in the recompense they hope to obtain, what will indemnify them for the expences they are sometimes obliged to incur. Accordingly, it appears to be a duty incumbent on scientific bodies, when they propose a subject which requires a considerable expence, not only to bestow a competent reward on the successful candidate, but also to indemnify those who have failed, for the expences they may have incurred.

CHAP. V.

Considerations on the influence of metallic and other substances, in producing contractions— The theory of GALVANI *combated—The different modes in which the electric fluid may be put in motion.*

VERY shortly after the discovery made by GALVANI, Professor VOLTA, one of the most enlightened naturalists of the present time, directed his attention to animal electricity, to the progressive attainments of which he has since so largely contributed by his experiments and inventions, more particularly by his electrico-galvanic apparatus, the discovery of which formed a new epoch in the science of galvanism.

His earliest communications on this subject, consist of two dissertations published in the Physico-Medical Journal of BRUGNATELLI, which, as their substance is contained in his letters subsequently addressed to Professor GREN, it is unnecessary to detail in this place. He shortly after transmitted the following letter to the editors of the Philosophical and Medical Journal of Leipsick.

"At

"At the commencement of the spring of the present year (1793), my attention was particularly directed to electricity, on account of the truly admirable phenomena which the celebrated Galvani, professor at Bologna, has discovered and described. By these phenomena he seems to have demonstrated, that there constantly exists, in animals of each species, an electricity of some kind, spontaneously excited by the vital force inherent in the organs, and by the animals themselves; or rather, that the electric fluid, when the equilibrium is naturally destroyed, no longer resides in the nerves, but exists in some continued movement, or in the effort it makes to establish itself in some part of the animal, according as it is more or less abundant. Having, in the first instance, repeated the different experiments of Galvani, I afterwards examined the results; and was thus enabled to make several discoveries which had escaped Galvani, and the other naturalists who had followed him in the tract he had, with so profound an intelligence, pointed out.

"In examining the principal questions, it has not hitherto been established, whether, in the galvanic experiments, the very powerful contractions excited in the muscles, and the movements of the limbs, on account of the double contact, in the first place on the muscle, and afterwards on the

the nerve of the animal, well prepared, and carefully dissected;—it has not, I say, been ascertained, whether these movements and contractions, which no one can doubt, are to be ascribed to the electric fluid, conveyed from one part to another by the means of a conducting arc, take place because that fluid directs itself by its own energy, or, on the other hand, by the simple force of the organs of the animal, towards such or such a part. In the latter case it may be denominated a true electricity inherent in the animal, as is asserted by GALVANI. Or, again, whether this sometimes happens, as I think I have seen in several instances, because the metals employed in the experiments, being directly applied to the parts of the animals replete with juices, are enabled, by themselves and by their own proper virtue, to stir, excite, and expel the electric fluid which was in a state of repose, so as that the organs of the animal merely act passively.

"Some time ago I had occasion to demonstrate, by indubitable experiments, that metallic substances, and charcoal of a good quality, are not only the most perfect conductors of electricity, but even become exciters by the means of simple contact. It was already known, that metals and charcoal possess the property of transmitting electricity very readily, wherever it is excited,

excited, or, in other words, when it endeavours to re-establish the equilibrium it has lost. But I was afterwards enabled to make the discovery, that the equilibrium of the electric fluid can be destroyed, and a new electricity created by those substances. It is in reality by themselves, and by their own virtue, so far as they act by impelling and forcing the electric fluid to enter into the superficies they touch, or to flow out from thence, that metals and charcoal excite that feeble electricity which can in no way be discovered by the common electrometers, however carefully they may be made, but which possesses at the same time a sufficient energy to convulse the nervous fibres and the muscles it encounters, without any friction or other mean, provided these substances be duly applied to water, or to bodies which have imbibed an aqueous humour, such as the nerves and muscles of animals, either living, or recently killed.

"But if these kinds of metallic coatings, consisting of one and the same metal, be applied to the nerves in two places, and if they be made to communicate with each other by a proper conductor, what is the result that ought to be expected? According to every probability, a small portion of the electric fluid will ooze out, and escape from one of the coatings to the other; but they will, by their equal effort, be mutually detrimental

trimental to each other; and consequently there will not be any transmissal from the one to the other, nor any circulation. It is thus proved, that it is necessary to have recourse to different metals, which, in proportion as they act on the body they touch by an unequal and even contrary force, transmit from one part to the other a pretty considerable quantity of the electric fluid, provided a conducting or exciting arc be employed, and carried to all the parts covered by the coatings.

"If these parts, as well as the intermediate ones, are sufficiently *deferent*, the electric fluid will be continually in circulation; and if, in this constant movement, and in each of the parts where it takes place, the fluid in question encounters nerves, which serve either for motion or sensation, it will so excite them, as that, according to the diversity of their functions, they will either produce a sensation, as happens to the point of the tongue, which is affected by an acid or an alkaline taste, in proportion as the fluid penetrates into or flows out of it; or they will excite contractions of the muscles and movements of the limbs, as happens very frequently when the electric fluid acts on the crural or brachial nerves, or on any others which are set aside for voluntary motions, and which are of a considerable extent. This is the reason of the pheno-

phenomena which have been too confidently ascribed to animal electricity, and which I am inclined to attribute to an electricity, either artificial, or excited by external agents.

"But, in the different experiments made by GALVANI, is there nothing to favour the existence of animal electricity? This I can neither maintain nor deny. I merely say, that all the experiments, in which metals of the same description are unsuccessfully employed, and in which it is necessary, to excite muscular contractions, to have recourse to different metals, are of no kind of efficacy in establishing the inherent electricity of the organs, the one which is called *active*, because the organs in this case appear to be altogether passive. There are certainly many instances in which the muscular movements cannot be excited, unless by the contact of metals of a different kind; at the same time that there are but few in which these movements are produced by the means of the same metal. Now, as a diversity which is scarcely perceptible, is sometimes the cause that metals having the same name, and of the same description, produce some effect, it would appear that considerable doubts may be entertained, whether, when the metallic coatings are absolutely the same, and produce notwithstanding muscular movements in the parts of prepared animals, the

denudated nerves of which are still endued with a very great share of excitability;—it may, I say, be doubted whether an imperceptible difference in the more or less superficies of the metals, &c. may not be the cause why the electric fluid is then excited, and made to pass from one part of the animal to another.

"Even when this animal electricity, admitted by GALVANI, has recently flown off, there still remains, by the means of an electrical stimulus, an incomparable and admirable excitability of the fibres, and principally of those belonging to the nerves. On another hand, the new principle of artificial electricity, discovered by me, which may tend to throw a great light on this subject, is still to be adduced, namely, the force and virtue of metals and charcoal, in exciting and expelling the electric fluid by the means of a simple contact with all humid bodies, which become, by this quality, so many conductors. This I have established by incontestible experiments, in which the bodies of animals had no concern whatever."

It has been seen above, that, according to M. VOLTA, the whole of the magic of galvanism consists simply in an artificial electricity, renewed whenever it is put in motion by the contact of conductors of a different nature. The latter, which act essentially, may, he thinks, be considered

dered as the primary exciters *(moteurs)*. GALVANI, on the other hand, was led to consider the fluid which has been named after him, as an electricity residing essentially in the animal organs. Agreeably to the theory of VOLTA, the electric fluid may be put in motion in three different ways, by the means of at least three conductors of a different nature brought into the arc or circle. The first of these modes consists of two metals, or conductors of the first class, each of a distinct nature, which touch each other directly by one of their extremities, and do not communicate by the other extremity, unless by the medium of one or several moist conductors, or conductors of the second class. In the application of the second mode, a single metallic conductor of the first class is placed between two humid conductors of a different nature, which communicate with each other. The third mode consists of establishing a communication between three conductors of a different nature. This curious inquiry into the action of metals, and other conducting substances, in galvanic experiments, will be best explained by the letters of M. VOLTA to Professor GREN, the substance of which is as follows*:

"If a tin bason be filled with soap-suds, lime-water, or a strong ley, which is still better, and

* Philosophical Magazine, vol. iv. pp. 59, 163, and 306.

 if

if you then lay hold of the bason with both your hands, having first moistened them with pure water, and apply the tip of your tongue to the fluid in the bason, you will immediately be sensible of an acid taste upon your tongue, which is in contact with the alkaline liquor. This taste is very perceptible, and, for the moment, pretty strong; but it is changed afterwards into a different one, less acid, but more saline and pungent, until it at last becomes alkaline and sharp in proportion as the fluid acts more upon the tongue, and as the activity of its peculiar taste and its chemical power, more called forth, produce a greater effect in regard to the sensation of acidity occasioned by the stream of the electric fluid, which, by a continued circulation, passes from the tin to the alkaline liquor, thence to the tongue, then through the person to the water, and thénce to the tin again. I explain the phenomenon in this manner, according to my principles; and indeed it cannot be explained in any other, as every thing tends to confirm my assertion, and to prove it in various ways. The contact of different conductors, particularly the metallic, including pyrites and other minerals as well as charcoal, which I call dry conductors, or of the *first class*, with moist conductors, or conductors of the *second class*, agitates or disturbs the electric fluid, or gives it a certain impulse.

Do

Do not ask in what manner: it is enough that it is a principle, and a general principle. This impulse, whether produced by attraction or any other force, is different or unlike, both in regard to the different metals and to the different moist conductors, so that the direction, or at least the power with which the electric fluid is impelled or excited, is different when the conductor A is applied to the conductor B, and to another, C. In a perfect circle of conductors, where either one of the second class is placed between two different from each other of the first class, or, contrariwise, one of the first class is placed between two of the second class different from each other, an electric stream is occasioned by the predominating force either to the right or to the left—a circulation of this fluid, which ceases only when the circle is broken, and which is renewed when the circle is again rendered complete. This method of connecting the different conductors will be more readily comprehended by turning to the figures, *(Plate* I.*)* where the capital letters denote the different conductors or exciters *(moteurs)* of the first class, and the small letters those of the second class. *Fig.* 1, and 2, express the two cases above-mentioned.

"I consider it as almost superfluous to observe, that when the circle consists merely of two kinds of conductors, however different or

however numerous the pieces may be of which each consists (as *Fig.* 3, 4, 5 and 6), two equal powers are opposed to each other; that is, the electric fluid is impelled with equal force in two different directions, and consequently no stream can be formed from right to left, or contrariwise, capable of exciting convulsive movements.

"There are other cases, however, and other modes of combination, where the powers are equally in eqilibrium, and where no current of the electric fluid can take place; or, at least, none of such a force as to make an impression on the tenderest nerves, or to excite any convulsive movement in the best prepared frog that may be placed in the circle, notwithstanding the intervention of two or more different kinds of metals. This is the case when each of these metals is placed between two moist conductors, or of the second class, and which are very nearly of the same kind, as *Fig.* 7; or when, in a circle of three pieces, two of them of the same metal, and one of a different metal, are so connected, that the latter is immediately between the other two, as *Fig.* 8.

"When one of the ends of the middle piece of metal A is immediately applied to one of the two pieces Z, but, instead of immediately touching with the other end, the other piece Z touches an intermediate conductor of the second class, either

either great or small, either a drop of water, a piece of raw or boiled flesh, or of sponge not moist, paste of meal, jelly, soap, cheese, or the white of an egg boiled to hardness, in this new combination, represented by *Fig.* 9, (where a conductor of the second class, *m*, is between two of the first class, A and Z) the powers are no longer opposed to each other; and this is sufficient to determine an electric stream. When *g*, therefore, in *Fig.* 9, is a prepared frog, it will always be violently agitated as often as this circle is made complete.

"It may be readily perceived that the two last experiments represented by *Fig.* 8 and 9, coincide with those announced by M. HUMBOLDT, where a drop of water, a small bit of fresh meat, or a very thin stratum of any fluid, performs the whole wonder. When another drop of water, or any other aqueous conductor, is applied between the other end of A and the other corresponding piece Z (as shewn *Fig.* 10), each piece of metal is insulated, as I shall express it, between two aqueous conductors: but then the powers from right to left, and from left to right, are again completely opposed to each other; consequently the electric stream is impeded, and the frog remains without any movement. It is, therefore, absolutely necessary that two different metals or conductors of the first class, should be

 in

in immediate contact with each other, on the one side, while with their opposite ends they touch conductors of the second class.

"We might consider this mutual contact of two different metals as the immediate cause which puts the electric fluid in motion, instead of ascribing that power to the contact of the two metals with the moist conductors. Thus, for example, in *Fig.* 1, instead of admitting two different actions, at least, in regard to the magnitude of the power, one where A comes in contact with *a*, and another where Z comes in contact with *a* also, by which an electric current arises in the direction from Z to A, we might suppose only one action at the point where A comes in contact with Z, which impells the fluid in that direction. In both suppositions the result, as may easily be seen, is the same. But though I have reasons for adopting the first as true rather than the second, yet the latter represents the proposition with more simplicity, and it may be convenient to adhere to it in the explanation, as it affords a readier view of it. We may then say, that in the cases of *Fig.* 3, 4, 5, 6, 7 and 10, no effect will be produced, because here there is no mutual contact of different metals: that the effect also, according to *Fig.* 8, will be null, because A, on two opposite sides, is in contact with Z and Z, and the actions there-

fore

fore are in equilibrium; and lastly, that an electric current will be occasioned in *Fig.* 9, by the action which arises from the contact of A and Z, and which is counteracted by no other contact of the like kind.

"Having seen the result of employing three pieces of metal, or conductors of the first class, viz. two of one kind and one of a different, when combined sometimes in one way and sometimes in another, with conductors of the second class, we shall now try what will be the result, according to my principles, with four pieces of metal, two of which are of one kind; for example, zinc, when connected with moist conductors of different kinds.

"I shall first observe, that when they are connected in a circle, as at *Fig.* 11, the powers which endeavour to put the electric fluid in a streaming movement, will be opposed to each other, and in perfect equilibrium, and that consequently no movement can take place in the frog, here supposed to be the moist conductor *a*, or a part of it, however irritable and well prepared it may be; and if the experiment be made with accuracy and the necessary precaution, so that the metals, in particular, be very clean and dry at the points of contact, it will perfectly confirm what I have above said: the frog will experience no agitation, no convulsive movement.

"These movements, on the other hand, took place, as might be foreseen from my principles, as

as often as I omitted one of the middle pieces, or changed the order.

"The conductors of the second class, which in all the figures are denoted by small letters, may be cups with water, in which the ends of the pieces of metal denoted by the large letters are immersed; or sponges or other bodies which have imbibed aqueous moisture. They may be either large or small; and may consist of one or more pieces, provided they be in proper contact: they may also be persons, if their skin be moistened at the places of contact, &c. By the last method the experiments will be very beautiful and incessant, when the circle consists of three or more persons (I have formed it frequently of ten, and even more), of two or more frogs properly prepared, and of four pieces of metal, two of silver and two of iron, tin, and particularly zinc. The change of effect, when you change the connexion, is striking.

"Let the position be as represented in *Fig.* 12, where *g* is the prepared frog, which the two persons *p*, *p*, hold in their hands, one on the one side by the feet, and the other on the opposite by the rump. Z, Z, are two plates of zinc, which are held also by these persons, and A, A, two pieces of silver, which are held by a third person, denoted also by *p*. It must not be forgotten that the hands should be very moist, as the dry

skin

skin is not a conductor sufficiently strong. As in this chain the actions of the electric exciters are opposed to each other, and in exact equilibrium, as may be readily perceived, no convulsion or agitation in the frog will take place.

"Now, let one of the metallic pieces A, Z, which stand between the two persons *p*, *p*, or between any other moist conductors, be left in combination as it is; and let the position of the two other metallic pieces A, Z, be reversed, by converting *Fig.* 12 into *Fig.* 13 (so that the actions, instead of being contrary, will act together to impel the electric fluid to one side or to produce the same current); or introduce between A and Z another person, or any other conductor of the second class, so that the chain be formed as in *Fig.* 14; or take away one of the pieces A, Z, in *Fig.* 12, and make the chain like those of *Fig.* 15 and 17; or, in the last place, remove the whole two pieces A, Z, either in the one or the other side, as represented *Fig.* 17 (by which means it will correspond with *Fig.* 1, as the whole chain *p*, *g*, *p*, *p*, may be considered as a single moist conductor of the second class); in all these combinations, which are represented by *Fig.* 13, 14, 15, 16, and 17, the actions arising from the metallic contacts are no longer contrary to each other, or in equilibrium, as they were in *Fig.* 12; consequently an electric stream is produced,

duced, and the frog *g*, which I suppose to be properly prepared, and which forms a part of the chain, will be violently agitated as often as the circle, when broken at any one place, particularly between metal and metal, is again restored.

"In regard to the experiment where a moist conductor, or one of the second class, is to be introduced between the two pieces A, Z (*Fig.* 14), that is, between two different metals, a drop of water, or a small bit of moistened sponge, or a thin stratum of any fluid, soap, or any other viscous matter, will be quite sufficient, as I have already observed respecting *Fig.* 9. This surprizing experiment I generally make in such a manner, that, instead of the piece of metal, I employ a cup or spoon filled with water, and then cause the person who holds the perfectly dry and pure stick of tin, to touch with that stick sometimes the perfectly dry sides of the spoon or cup, and sometimes the water contained in them. It is wonderful to see, that as by the latter method the violent agitation of the frog never ceases, the first method, which corresponds with *Fig.* 12, does not produce the least irritation; unless by accident there be a small drop of water, or a thin stratum of moisture, at the place of contact, by which the case represented *Fig.* 14 would be restored. This may serve to shew with what care and attention the experiment must be made,

made, in order to guard against error or deception, which might so easily arise, and every where exhibit anomalies.

"When I introduce water or any other moist body, great or small, not merely between one pair of metallic pieces, A, Z, as *Fig.* 14, but between two pairs, as represented *Fig.* 18, each piece of metal is between like moist conductors, and by these means all the actions are again rendered contrary, or brought into equilibrium; or, according to the other mode of viewing the matter, there is no longer any action, for want of the mutual contact of two different metals, which, as we have seen, is certainly necessary to excite an electric current; and it is always found that the frog experiences no agitation.

"I shall not enlarge farther on these combinations, which may be varied ad infinitum with a greater number of metallic pieces, and by which one may be enabled to foretell the phenomena which, according to my principles, will always be found to take place. It will be sufficient, for the present, to draw this conclusion, that in a circle consisting merely of two conductors, however different they may be, their mutual contact can produce no electric stream sufficient to excite sensibility, or muscular movement; and that, on the contrary, this effect infalliby follows as often as the chain is formed of three conductors, one

of

of one class, and two different from each other of another class, which come into mutual contact with each other, and that this effect will be stronger, the greater the difference is between the latter; that in other cases, where there are more than three different conductors, the effect either is not produced, or will be produced in different degrees, according as the forces called forth by the different combinations, which will be expanded at each heterogeneous contact, and which are often in opposition, and endeavour to impel the electric fluid in opposite directions, are perfectly in equilibrium with each other (which must be a very rare case), or when the sum of those which exert themselves in one direction is more or less exceeded by the sum of those which act in another direction.

"I shall here, however, leave the two complex combinations, and return to the simple cases, those with three different conductors, represented by *Fig.* 1, which are more demonstrative; or, in other words, those with two different metals or conductors of the first class, which are in contact with each other, and are applied on the other side to moist conductors, or conductors of the second class. This method has been commonly employed since GALVANI's discovery, and is in exact proportion with the diversity of metals, on which I consider the whole phenomena to depend.

"The

"The other method of combination, which is expressed by *Fig*. 2, or that of a metal placed between two different moist conductors, for example, between water on the one side, and an aqueous, saponaceous, or saline fluid on the other, I discovered in the autumn of 1794; and though since that period I have repeated the much varied experiments of different persons, both foreigners and others, among which was that of M. HUMBOLDT, and though I wrote to several correspondents respecting it, that light has not yet been thrown on this new phenomenon which it seems to deserve.

"The singular circumstance before mentioned, in regard to the acid taste when the tongue is brought into contact with an alkaline liquid, belongs, as you may perceive, to this second method of exciting the electric fluid, and putting it in circulation (if the tin vessel be touched on the outside by the hand moistened with water, and on the inside by the alkaline liquor), and shews that this current is no less strong and active than that excited by the first method, viz. by employing two sufficiently well-chosen metals, such as lead and copper, iron and silver, zinc and tin. I must here observe, that though with tin alone, placed between water and an alkaline liquor, you obtain nearly the effect which is produced by two of the most different metals, as silver and zinc, combined

bined with any conductor whatever of the second class; you can obtain the same, and even in a higher degree, with iron alone or silver alone, when the iron is introduced between water on the one side and nitrous acid on the other, or when the silver is applied between water and a solution of sulphure of pot-ash.

"If you take a frog, the head of which has been cut off, and which has been deprived of all life by thrusting a needle into the spinal marrow, and immerse it, without skinning it, taking out the bowels, or any other preparation, into two glasses of water, the rump into one, and the leg into the other as usual, it will be strongly agitated and violently convulsed when you connect the water in both glasses by a bow formed of two very different metals, such as silver and tin or lead, or, what is better, silver and zinc; but this will by no means be the case when the two metals are less different in regard to their powers, such as gold and silver, silver and copper, copper and iron, tin and lead. But what is more, the effect will be fully produced on this so little prepared frog when you immerse in one of the two glasses the end of a bow merely of tin or zinc, and into the other glass the other end of this bow, which has been rubbed over with a little alkali. You may perform the experiment still better with an iron bow, one end of which has been

been covered with a drop or thin coating of nitrous acid; and beyond all expectation, when you take a silver bow having a little sulphure of potash adhering to the end of it.

" *Fig.* 19 represents the form of this experiment, where *g* is the frog, *a*, *a*, the two glasses with water, A the bow formed of one single metal, and *m* the drop or a thin stratum of a mucous, saline, &c. fluid, with which the bow has been rubbed over, and which on this side is between the metal and the water.

" The very considerable difference in regard to the quantity of effect in the before-mentioned experiments already shews, that if the electric stream excited by contact is strongest towards a certain metal, when that metal is placed between a certain fluid on the one side, and another fluid on the other, there are other fluids which produce a greater effect with another kind of metal; so that it will be necessary to discover by experiment the particular arrangement of conductors suited to each metal, in which the fluids or conductors of the second class must be disposed according to their activity. I have paid great attention to this circumstance, and have formed several tables, which I shall publish as soon as I have brought them to perfection.

" I shall here, however, only observe, that in order to class, in some manner, the innumerable different moist conductors of this kind, I distinguish

guish them into aqueous, spiritous, mucous, and gelatinous, saccharine, saponaceous, saline, acid, alkaline, and sulphurous (livers of sulphur) liquids; that I make subdivisions in the acids, down to the best known simple mineral acids, (as I find in this respect great difference between the nitrous and the muriatic acids,) comprehending the principal vegetable acids and the acid of galls; and do the same in regard to the saline fluids, according as they are solutions of neutral salts, earthy salts, and particularly metallic salts.

"When it can be determined in what order all these kinds of fluids follow each other, in regard to the power in question, for the metal A, and another for the metal B, &c., we shall then be in a condition to determine what place must be assigned to a great number of other heterogeneous fluids, whether mineral, vegetable, or animal, which belong to several of the above classes. In general, the order for the greater part of the metals hitherto observed is as follows: 1st, pure water; 2d, water mixed with clay or chalk (which shews a pretty different effect when the before-mentioned experiment is made with two glasses, a bow of tin or zinc, and a properly prepared frog, which has a sufficient degree of vitality); 3d, a solution of sugar; 4th, alkohol; 5th, milk; 6th, mucilaginous fluids; 7th, animal gelatinous fluids; 8th, wine; 9th,

9th, vinegar, and other vegetable juices and acids; 10th, saliva; 11th, mucus of the nose; 12th, blood; 13th, brains; 14th, solution of salt; 15th, soap-suds; 16th, chalk-water; 17th, concentrated mineral acids; 18th, strong alkaline leys; 19th, alkaline fluids; 20th, livers of sulphur. With some metals there is, however, a considerable deviation from this order, in regard to livers of sulphur, alkaline fluids, and the nitrous and saline acids.

" As to the metals, which in their position between these different fluids are more or less proper for the electric effect in question, I have found in general, that tin exceeds all others, and that silver is the worst; except when one of the fluids betwixt which the silver is placed is water, or any other aqueous conductor, and the other liver of sulphur: in this case silver far exceeds zinc, and even tin. Iron also produces a much greater effect than any other metal, when it is in contact, on the one side, with mere water or an aqueous conductor, and on the other with the nitrous acid, were it even only a drop. The excitement occasioned in both cases is wonderful; since it exceeds, as I have already remarked, that produced, according to the usual method, by means of a double metallic bow, even of different metals, as zinc and silver, applied to conductors of the second class of the same kind.

 It

It is sufficiently strong and powerful to produce convulsive movement in a half-prepared frog, the bowels of which have not been taken out, when one of the two moist conductors is a concentrated alkaline solution, and the metal placed between them is zinc, or rather tin. With other metals and other fluids you can seldom produce convulsions in a frog, if it be not perfectly prepared, or at least embowelled.

" The reader will readily perceive, that when a bow of one and the same metal touches with both its ends the same kind of saline water, the same acid, the same alkaline fluid, &c. an electric stream will not take place, as happens also when it touches on each side merely water: in that case two opposite actions are opposed to each other, and keep each other in equilibrium. That these contrary powers, however, may be in perfect equilibrium, it is necessary that the fluids applied to both ends of the homogeneous metalline bow be exactly of the same kind and of the same strength. For this reason the most careful attention and a certain dexterity are required, in order to ensure success to the experiment, which I have often performed to the great astonishment of the spectators, and which any one may repeat as was done by my friend HUMBOLDT. That philosopher has already published some of the most striking and decisive of these experiments

ments in his second letter; and I shall here give a more particular account of them.

"Having placed a completely or only half-prepared frog as usual in two glasses of water, take a very clean bow of silver (it will be best when it has been washed with water from the glasses), and immerse both ends of it at once, or the one after the other, in the glasses, no agitation of the frog will be occasioned. Repeat the experiment, after you have daubed over one end of the bow with the white of an egg, liquid glue, saliva, mucus, blood, a solution of tartar, or any other fluid or conducting substance sufficiently different from pure water. First, immerse the pure end, or that moistened merely with water, in the water of one of the glasses; and afterwards the other end, daubed over with the above substances, in the water of the other glass; you will then infallibly produce a convulsive movement in the frog, and several times in succession, if you draw out the bow and again immerse it until nothing more of the above substances is left adhering to the metal, or until the metal, with its ends in both the glasses, touches only pure, or nearly pure, water. Daub both the above substances uniformly over both ends of the bow, and immerse them at the same time in both the glasses of water, and no convulsions will arise. They will often be produced in newly prepared

and highly irritable frogs, when the saline fluid, or, in general, the substance with which the two ends of the bow are daubed over, is not perfectly the same, or when the substance at the one end is more diluted than at the other, &c. Wash and clean carefully the one end of the bow, daub over the other more or less, and convulsions will be again produced as soon as the circle is made complete by the double immersion of the bow. Clean both ends completely, and no agitation will arise, as in the first experiment.

"For comparative experiments of this kind, I would recommend viscous fluids or substances rather than saline, because the latter are too soon dissolved in the water. It oft-times happens that the convulsions of the frog, when it is completely prepared and highly irritable, take place, though both ends of the metallic bow are daubed over with the same kind of saline fluid. The cause of this is, that when one end is immersed in the water after the other (and it may be easily seen that it is impossible to do so in a moment with sufficient accuracy), the one end of the bow loses a portion of its saline substance sooner than the other, or at least the adhering part is more diluted by the water, so that the fluid with which both ends have been daubed over is no longer the same.

" For these experiments I would also recommend silver, as a metal that is less liable than others to be attacked and changed by saline and other liquids. Tin, lead, copper, and in particular iron, are more susceptible of lasting variations; so that bows of these metals, and of iron above all, retain for a long time the power of producing convulsions in a newly prepared and highly irritable frog, even when both the ends of the bow are immersed in two glasses of water, although the places of the metal, attacked by any of the saline fluids, have been carefully washed and cleaned. A superficial alteration in the metal is sufficient to produce this change, as may be easily seen. These variations often shew themselves to the eye by a yellow blackish spot, &c. which it is difficult to remove. I do not here speak of lasting variations, that proceed to a greater depth, which can be produced in the end of the metallic bow, and particularly in iron, when its hardness is changed; a process by which such a bow can be rendered capable of producing not only convulsions in frogs, but also a particular sensation on the tongue, and light before the eyes, if both its ends, made perfectly clean, are only brought into contact with pure water. These, and many other experiments of the like kind, form the chief subject of my first letter to the Abbé VASSALLI, Professor of Natural Philosophy

sophy at Turin, written in the beginning of the year 1794, and afterwards published with the other in BRUGNATELLI's Journal.

"If silver be less exposed to be attacked by saline and other fluids (except by liver of sulphur, which instantaneously renders it black); if it be less susceptible of considerable and lasting variations, and has therefore this advantage over other metals, that it is liable to fewer irregularities; tin, on account of its greater activity, that is, the strength of the effects which it produces by being brought into contact with almost all moist conductors, as I have already observed, is to be preferred to silver, and in a certain degree to all other metals. The experiment I have already described with a tin bason filled with an alkaline fluid, and held in the hands moistened with water, by which an acid sensation is excited on the tongue when brought into contact with the above fluid, is a proof of it; for it would be vain to expect a like effect from a bason of lead, iron, or copper, and much more so from one of silver. With the latter it would be obtained only when it contained liquid liver of sulphur; and in that case the acid taste would be pretty strong.

"The electric fluid is excited also with the greatest strength and activity, when the metal is tin, between water and a saline fluid: but it will be excited with still greater energy to produce an acid

acid sensation on the tongue when the tin is between water and an insipid mucilaginous fluid; or when the experiment is made with a tin bason filled with a solution of gum, liquid glue, white of an egg, &c. The other metals, in like circumstances, produce some effect, but much weaker: silver produces the weakest, except with liver of sulphur, as I have already observed.

"A like experiment, which I made three years ago, and exhibited to various persons, not with two different fluids and one metal, as in that above described, but contrariwise, with two metals of a different kind and a fluid, is already known. I took a bason of tin (one of zinc is better), placed it on a silver stand, and filled it with water. When any of the persons in company applied the tip of his tongue to the water, he found it perfectly tasteless as long as he did not touch the silver stand; but as soon as he laid hold of the stand, and grasped it in his hands well moistened, he experienced on the tongue a very perceptible and pretty strong acid taste. This experiment will succeed, though the effect is proportionably weaker, with a chain of several persons who hold each other's hands, after they have been moistened with water, while the first applies the tip of his tongue to the water in the bason,

bason, and the last lays hold with his hands of the silver stand.

"If these experiments, in regard to the taste excited on the tongue by the action of two different metals, are striking, the others, in regard to the taste excited, modified and changed by one metal between two different fluids, are no less so, and they are also newer. They are still interesting on this account, that they discover to us the cause of that taste often perceived in water and other liquids, which is more or less considerable or various when drunk from vessels of metal, and particularly of tin. When the outer extremity of the vessel is applied to the under lip, rendered moist by the saliva, and the tongue is extended so as to be in contact with the water, beer, wine, &c. in the vessel, or when the tongue is bent as is done in drinking, is there not then a complete circle, and is not the metal between two more or less different liquids, that is, between the saliva of the under lip and the liquor in the cup or vessel? A stronger or weaker electric stream must thereby be occasioned, according as the fluids are different—a stream which will not fail in its way to affect the sensible organs of the tongue in the said circle.

"Besides the two methods already considered, of producing an electric current, that is, by means

of

of one or more moist conductors, or conductors of the second class placed between two different metals or conductors of the first class; or contrariwise by means of a conductor of the first class placed between two of the second class, also different; there is still a third method of exciting the electric fluid, though in a degree so much weaker, that it is scarcely capable of causing convulsions in a perfectly prepared frog, in which there is still a strong degree of vitality. This new method consists in forming the circle of three different conductors, all of the second class, without the intervention of one of the first or a metal one. Some think they find in this method a strong objection against my principle.

Fig. 20, represents this third method compared with the other two*. In the experiments of Professor VALLI, respecting which so much noise has been made without any reason, *t* represents the leg of the frog, and particularly the hard tendinous part of the *musculus gastrocnemius*; *m* the rump, or the muscles of the back, or the ischiatic nerves, to which the said tendinous parts are applied; and *a* the blood, or the viscous saponaceous or saline fluid, applied to the point of contact.

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* See Plate I.

"I have

"I have fully described this new method, where no metal is used, in my third and fourth letter to Professor VASSALLI, written in the autumn and winter of the year 1795. I have there shewn, that these new facts, far from altering my ideas and principles, serve rather to establish them; and that they render more general the principle that the conductors, by heterogeneous contact, that is, of two different from each other, become exciters of electricity, and confirm the beautiful law arising from it, that to produce an electric stream, the circle must necessarily be formed of three different conductors. You now see in what the whole secret, the whole magic consists; and that it depends not merely on metals, as might have been believed, but on all the different conductors. As long as we adhere to these principles, it will be easy to explain all the before-mentioned experiments without being reduced to the necessity of having recourse to any imaginary principle, or any peculiar and active electricity of the organs. By their assistance you will be enabled to invent new experiments, and to foretell the result of them, as I have several times done, and still do daily. If you, however, abandon these principles, you will find nothing but uncertainty and contradiction, and the whole will be an inexplicable problem."

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The following postscript to these letters was afterwards published by Professor VOLTA.

"Some new facts, lately discovered, seem to shew that the immediate cause which excites the electric fluid, and puts it in motion, whether it be an attractive or a repulsive power, is to be ascribed much rather to the mutual contact of two different metals, than to their contact with moist conductors. But, though it cannot be denied that in the latter case there exists an action, it is proved that it exerts itself in a far more considerable degree when the two metals mutually touch each other. There arises by the mutual contact, for example, of silver and tin, an action or power by which the former communicates the electric fluid, and the latter receives it; or the silver suffers it to escape, and the tin attracts it. This produces, when the circle is rendered complete by moist conductors, a stream, or continual circulation of the fluid. When the circle is complete, there is an accumulation in the tin at the expence of the silver; which indeed is very small, and far under the point necessary to enable it to announce itself by the most delicate electrometer. I have however been able, by the assistance of my condenser, constructed on a new plan, and still better by NICHOLSON's doubler, to render it very perceptible: I shall here communicate the result

result obtained by my experiments, which I made some time ago with great satisfaction.

"*Experiment* I. The three plates of the doubler are of brass. I took two strong wires, one of silver and the other of tin, and brought the former into contact with the moveable plate, and the other with one of the fixed plates; while they both rested on the table, or, what is better, on moist pasteboard, or any other moist conductor, so as to be in communication by the intervention of one or more conductors of the second class. I suffered the apparatus to remain some hours in this state, then removed the two wires, and put the machine in motion. After 20, 30, or 40 revolutions (or more when the atmosphere was not dry, or the insulation imperfect), I brought one of my straw electrometers into contact with the moveable plate, and observed indications of positive electricity (+E) which arose to 4, 6, 10 degrees, and more. If I suffered it to touch the fixed plates, I had the corresponding indications of the opposite kind of electricity (—E).

"The silver, therefore, poured the elastic fluid into the brass plate when it had been some time in contact with it; and the tin attracted it from the other plate, which was also of brass, while in contact with it. This was confirmed by the

the following experiment, which is a real *experimentum crucis*.

"II. I reversed the experiment, so that the silver was in contact with one of the fixed plates, and the tin with the moveable one. The electricity which I obtained from the latter, after the apparatus had remained a sufficient time in that position, was negative (—E); while that of the fixed plate was positive (+E).

"III. I applied only the tin wire to the moveable plate, and insulated the two fixed ones, or brought them into communication with the table or any other moist conductors with which the tin wire was in contact. This simple contact of the tin with the brass, of which the moveable plate consists, is sufficient to excite in it a very small degree of negative electricity; only a longer time is required.

"Those acquainted with the action of electric atmospheres, and the construction of the doubler, will need no farther explanation, to enable them to comprehend the mode of action of this very ingenious instrument; how the electricity, once obtained from the moveable plate, must occasion an opposite kind in the fixed plates, and *vice versa*; how the opposite kinds of electricity are increased by each revolution of the machine, &c. In the present experiment, therefore, when the moveable plate is —E, the fixed plate must be +E.

"III.

"III. This is the reverse of the former. The piece of tin was applied to one of the fixed plates, and the metallic one was insulated from all metallic contact. The result was now reversed; that is, the fixed plates were electrified negatively, and the moveable one had positive electricity.

"All these experiments succeed much better, and in a shorter time, if, during the mutual contact of the different metals, the moveable plate be opposite to either of the other two that are fixed; but still better when a piece of thick paper, such as a card, not moist, and of a thickness equal to the intermediate space, is placed between the two plates that stand opposite to each other. It is of advantage to leave the card some time in its place, and not to remove it till the moment when the metals in contact are removed and the machine put in motion. To render the insulation complete, and make the contact of the metals immediate, without the least moisture, which would be highly prejudicial, it will be proper to place the apparatus in the sun. Half an hour, and often less, will then be sufficient to obtain the required electricity, &c.; whereas, in other cases, several hours are necessary before the desired result can be obtained. A representation of this experiment is exhibited by *Fig.* 21, 22, 23 and 24, (*Plate* I.) LLL (*Fig.* 21 and 22) are

are the three brass plates of the doubler; A the the piece of silver which is in contact with one of these plates; E the piece of tin applied to the other plate, which is opposite to the former; *a a*, the moist conductor, or chain of moist conductors which form a communication with the pieces of metal. When the silver, as in *Fig.* 21, is in contact with the anterior moveable plate, it gives up to it a little of the electric fluid, and the latter accumulates as much of it as possible; consequently the electricity of the plate becomes positive, as the sign + of the plate shews: whereas the tin attracts the electric fluid from the corresponding fixed plate, which by these means has negative electricity, as the sign (—) of the plate indicates; and it even communicates this electricity to the other fixed plate, which therefore has the sign (—) also.

" In *Fig.* 22, every thing is reversed: the moveable plate is negatively electrified (—E), while the two fixed plates become positive (+E).

" Lastly, in the 23d and 24th Figure, it is seen that the tin abstracts the electric fluid from the brass plate with which it is in contact. This plate is therefore negatively electrified, or has —E; and by the action of its atmosphere occasions positive electricity (+E) in the other plate standing opposite, which is in communication, either with the third plate, as *Fig.* 23, or,

 what

what is still better, with other conductors, as *Fig.* 24. These opposite electricities increase afterwards with each revolution of the machine; the action of which, according to the theory of electric atmospheres, produces this effect to the degree mentioned, and justifies the appellation of doubler of electricity, which has been given to this instrument.

"I now come to the experiments, which shew that we are to seek for the cause which calls forth the action of the electric fluid; which excites it, of whatever kind it be; determines its transition, &c. much rather in the mutual contact of the metals, than in the contact of the moist conductors with these metals. Though, according to every circumstance, we must admit some action of this kind in the latter contact, it cannot be denied that the former is certainly the most effectual. At present I shall only mention the two following experiments, which I contrived in such a manner that they may serve to explain a question of this kind.

"V. I left the two fixed plates of brass without making any alteration; took off the third moveable plate, and supplied its place by one of tin; and arranged the machine in such a manner, that the latter stood opposite to one of the other two plates. I then applied to this tin plate a bit of brass, and to the opposite fixed plate of

of brass a piece of tin. After a convenient time, (for example an hour, when the weather was perfectly dry), I took away the two pieces of metal, or only that of brass, and made the moveable plate of tin, which was in contact with the piece of brass, to revolve about thirty times. It then gave me very perceptible marks of positive electricity.

"VI. I reversed the former experiment, and made the piece of brass touch the brass plate, and the piece of tin the plate of the same metal. I, however, obtained nothing, or almost nothing; even when the apparatus was left a much longer time in that situation, and when the machine had made twice or three times as many revolutions.

"These two experiments are represented by *Fig.* 25 and 26; where L is the piece of brass; E that of tin; and *a a* the moist conductors which connect the two different pieces of metal.

"In the arrangement of *Fig.* 26, the same contact of different metals, viz. brass on the one side, and tin on the other, with the same kind of moist conductor, takes place, as well as in the preceding experiment of *Fig.* 25. The addition of the electric fluid in the one, and the abstraction of it in the other, ought therefore equally to take place, though in an inverted order, when the action on the fluid calls forth the moving

 power,

power, by this contact of the two metals L, E, with the moist conductor between them; and yet this is not the case, as no signs of electricity are obtained even after a long time, and when the machine has been caused to make twice or three times as many revolutions. The condition essentially necessary to obtain electricity is, that the different metals must be in contact with each other, which is the case in *Fig.* 25, but not in *Fig.* 26.

"When the machine has been repeatedly turned, something may be obtained. This arises either from some small remains of old electricity, which could not be destroyed or dissipated in the time during which the arrangement of *Fig.* 26 was continued; or even from fresh electricity, which the moveable plate may have obtained from the atmosphere or vapours during the pretty considerable time of the machine being in a state of revolution; or some accidental difference, either between the two tin or the two brass pieces, may be the cause of some action on the electric fluid, or of some derangement in regard to the equilibrium. In the last place, the contact of the moist conductor with the tin on the one side, or with the brass on the other, may have a different action, which, in my opinion, must be very small, but yet is not entirely without effect.

"As it is now proved that, according to the arrange-

arrangement of the sixth experiment, nothing, or almost nothing, is obtained by 40, 60, and even 80 revolutions of the doubler, while a great deal is obtained by that of the fifth with 20 or 30, we must therefore conclude that the contact of two metals of a different kind with moist conductors, without the mutual contact of these metals themselves (which is wanting in the sixth experiment, where brass is in contact with brass, and tin with tin), produces nothing, or almost nothing; and that, on the contrary, the mutual contact of the two metals of a different kind, which takes place in the fifth experiment, produces the whole, or almost the whole, effect."

CHAP. VI.

Considerations on the organization of animals—System of VALLI *combated—Facts which prove the dissimilitude between galvanism and electricity—Metallic magnetism and galvanism compared—Relations between the galvanic influence and the muscular, nervous, and vascular systems of animals—Inquiry into the source from whence the respective forces of the nerves and muscles emanate.*

THE work of our learned countryman, FOWLER, intitled "Experiments and Observations relative to the influence lately discovered by M. GALVANI, and commonly called Animal Electricity," appeared about the time when the earliest inquiries of Professor VOLTA, contained in the preceding chapter, were given to the public, that is, in 1793. After a few reflections on the fortunate accidents which have given birth to so many important discoveries, he observes that the phenomena of galvanism are in a manner supernatural. In repeating the experiments, it would appear that the inquirer would be enabled to penetrate into the great secret of life and

and animality. The existence of an animal is, as it were, prolonged after its death; and such are the surprizing results of galvanism, that the spectator who witnesses this seemingly prolonged existence, is almost led to entertain a hope that death may finally be averted.

Our author now proceeds to take a rapid view of the animal organization, as it may be made susceptible of a general influence, such as the one which forms the basis of his inquiry. He begins by pointing out the structure and general disposition of the muscles and nerves, the common properties of which he afterwards details. He remarks that the mode by which an external agent excites irritability has not been hitherto explained; and that this is one of the primary facts, called *laws of nature*, relative to which we are in need of data, to enable us to reason fully on it. He points out the different stimulants, which he divides into internal and external, the former of them consisting of the various fluids applied to the muscles, to enable them to act, such as the blood, in the case of the heart, the aliments in that of the stomach, &c.; and the latter of the impression of extraneous bodies, whether solid or fluid, on the surface of the muscles.

The discussion into which our author enters in the commencement of his work, may be re-

duced to these simple facts, that there are, in the musculo-nervous economy of an animal, two systems of organs very different from each other; each of them governed by a particular influence, namely, irritability in the case of the muscles, and sensibility in that of the nerves. These two influences are reciprocally modified, and are sometimes dependent, and at other times independent of each other, the latter, sensibility, having an immediate connexion with the soul. Such, he observes, is the analysis of the progress made in the investigation of this part of the animal organization, at the time when new facts, and new experiments, gave rise to and produced a new influence, by the discovery of galvanism.

The Italian naturalists, by whom so many experiments have been made on this subject, have not hesitated to ascribe to common electricity the different facts and phenomena they have noticed. They have even carried the analogy still further, and have deemed themselves authorized to compare the muscular and nervous systems to the external and internal surfaces of the Leyden phial, between which, according to Franklin's theory, there exist, when it is charged, two opposite states of electricity, one of the two surfaces being electrified positively, and the other negatively. This also, observe the Italian physiologists, is the case with the nerve and the

muscle;

muscle; and this happens by the means of a certain faculty in the animal organization, by virtue of which one of the two systems is charged at the expence of the other. Examples of this are to be found in the electrical fishes, such as the torpedo and the eel of Surinam, by which this faculty is displayed, in the medium even of a liquid conductor of electricity.

Without either admitting or rejecting this hypothesis, FOWLER subjects it to a very severe scrutiny. Among other subjects discussed in his work, in which nature is interrogated with great sagacity and perseverance, he inquires whether it is in reality the electric fluid which is made to act. Whether, this being granted, its action is similar to that of the Leyden phial. And, lastly, whether the influence in question is propagated by the means of the nerves, muscles, and organic vessels.

After having given a short sketch of the history of the discovery of galvanism, he confirms what had been already noticed by the Italian naturalists, namely, that metals are the best agents in the experiments, and that the contact of two different metals is an essential condition. In particular instances, in which a single metal has produced contractions, he thinks that this has either been owing to the pain felt by the animal, which was still alive at the time of the contact, or because the metal, however pure it might apparently

rently be, contained a portion of alloy, or of solder*. He attaches some importance to the choice of the metals; and observes that zinc on the one hand, in contact on the other either with gold or silver, produces the most striking effects. With the aid of these metals he frequently re-excited contractions more than twenty-four hours after they had ceased. In making this experiment the nerve was coated with tin, and a different metal employed to establish the battery, from the coating to the muscle.

It was found by this naturalist:

1st, That the bulk of the metals employed in the experiment, and the extent of the surface brought in contact, had a considerable influence in augmenting the effects.

2dly, That water may be employed to establish a communication between the metals in contact, and the denudated nerves.

3dly, That the duration of the phenomena depends on the season, the nature of the animal's death, &c. The author frequently succeeded in

* It will be seen in the sequel, that experiments made at a subsequent period have proved that this circumstance is not of so much importance as had been before apprehended, and that galvanic contractions may be produced without the necessity of any metal being employed in the apparatus.

exciting

exciting contractions in a frog, the head of which had been cut off three days before.

The faculty of exciting, or bringing into action the galvanic influence, should, however, he observes, be distinguished in the apparatus from that by which it is conducted or transmitted. His attention appears to have been particularly directed to this conducting property, between which and electricity he noticed a striking analogy. Notwithstanding metals are excellent conductors, he found this not to be the case with the metallic oxydes*. The salts which have these oxydes for their bases, are but bad conductors.

Substances which do not possess the property of conducting the electricity, deny at the same time a passage to the influence in question, unless they be in a humid state. It appears to pass through the substance of metals, when their surface is coated with wax, or with any other non-conducting substance. It is readily transmitted

* In the new chemical nomenclature, the name of oxydes is given to the combinations of metals with the oxygenous principle which is imparted to them either by the air, by water, or by the acids, and converts them into a pulverulent substance, variously coloured, according to the metal from which it is formed, and to the quantity of oxygen which is appropriate to it. This modification of metals was formerly denominated *metallic calx*.

through

through gold or silver chains; but not with an equal facility through brass chains, unless they are forcibly extended. This tension produces a more perfect contact between the rings; and this condition is the more essential, as the smallest layer of air opposes an insurmountable obstacle to the galvanic influence. The temperature of the conductor may be varied in a certain degree, without influencing the effects. Ice, when perfectly dry, is not a conductor. Contractions may be excited in a frog without its being skinned. For this purpose, nothing more is required than to place the animal on zinc or tin, and to touch some part of it with silver, taking care that the latter metal and the zinc or tin should be in contact. This experiment succeeds equally well when the frog is immersed in water.

Doubts having arisen as to the necessity of comprehending the muscle in the circuit or battery, and the result of several experiments having seemed to indicate that this condition is not essential, FOWLER was enabled to ascertain that it really is so. He observes, that the incertitude on this head may be accounted for by the humidity with which, in certain instances, the surfaces are covered, and which must unquestionably perform the office of a conductor. By this circumstance, which enables the nervous and muscular systems to contribute at the same time to the

effects

effects of the galvanic influence, Doctor VALLI was more particularly led to the comparison he drew between these effects and those of the Leyden phial. Now, observes FOWLER, in the case of the latter, a single conductor, applied to the two surfaces, established the equilibrium between them by the common explosion; while in that of the galvanic influence, two metallic substances are invariably required. A frog, placed in an electric bath, and in a manner inundated with electricity, whether negative or positive, is nevertheless equally susceptible of galvanism.

The equilibrium between the two coatings of the Leyden phial is likewise established by applying the exciting arc to either of them. But such an indifference does not exist in the prepared frog, in the case of which the contractions are much more violent, if the conductor be applied in the first instance to the muscle, and afterwards to the coating of the nerve. In favour of his hypothesis, VALLI contends that a certain space of time must be left to the prepared animal, to enable it to recover the faculty of contracting itself, a contraction having been already produced, because the Leyden phial is re-charged during such an interval. FOWLER urges in reply, that the same phenomenon is observed in experiments made on the irritability of the heart, when that viscus is taken out of the animal. The excite-

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ment by which it is produced must likewise act by intervals; but it will not on that account be argued that irritability and galvanism are one and the same thing, and that the heart also is a Leyden phial. This part of the system of the Italian naturalist in question may, however, fall to the ground, without its following that electricity and galvanism are two different agents. An approximation of them is established by so many analogies, as to dispose the observer to entertain a belief of their identity. This persuasion FOWLER combats by the following arguments.

The primary cause of the electric phenomena consists invariably of motion; instead of which, in galvanism, motion is the effect and not the cause. In the case of the above cited phenomena, a single conducting substance suffices; but two are required to render the influence of galvanism manifest. In electric animals, such as the torpedo, the effects are subjected to the influence of their will; but in the case of the influence of galvanism, the will of the animal is not consulted. Certain conductors which are highly efficacious in electricity, are but indifferently so in galvanism; and *vice versa*. The most delicate electrometers do not indicate the influence of the latter, which is insensible to the ordinary perceptions. It is a well known fact, that electricity exhausts irritability, which galvanism,

nism, on the contrary, appears to augment. On this head FOWLER observes, that a frog which had been some time dead, and which did not, when subjected to the galvanic influence, afford any token of sensibility, began at length to manifest contractions which augmented afterwards.—To continue his reasoning:—while electricity disposes the muscles to putrefaction, galvanism, on the other hand, seems to diminish this tendency. It is said that the leaves of the sensitive plant, when electrified, display the movements peculiar to that plant; an effect which was not produced by galvanism, when a similar application of its influence was made. The torpedo does not appear to be itself affected by the electric phenomena it produces on other animals; while, on the other hand, the animals in which galvanism is inherent, are themselves fully susceptible of its influence.

To the evidences of dissimilitude which subsist between galvanism and electricity, our author annexes a particular fact, which furnishes an exception to the reciprocal independence of galvanism and of the will, such as he had observed, in the course of his experiments, in particular cases. Frogs in a healthy state were rarely acted on by the ordinary processes of galvanism; but as soon as the sciatic nerves had been divided, and the influence of the will on the movements of the extremities

extremities in this way suspended, the contractions produced by galvanism were as powerful as if the legs had been entirely separated. This was not owing to the contact of the metal with the wound, which was carefully avoided; and even when the former was brought in contact with the denudated nerve, the contraction did not ensue unless the nerve had been previously divided. It is known that the will has not the power to put a stop to the contractions produced by electricity; but it may be seen here, on the contrary, that the galvanic movements become more powerful in proportion as the will is less enabled to thwart them. If these effects are not electric, and if the intervention of metals is constantly requisite to produce them, they must, observes FOWLER, be due to some new and hitherto unknown property in the metals themselves. But, on another hand, the presence of metals is not the only condition required: a given state of the animal organization is also necessary.

Such are the principal conclusions our author draws from the experiments contained in the first section of his work. In the second, he inquires whether magnetism (the mineral magnetism, properly so called) has any connexion with the galvanic influence. His inference is, that the contractions excited by a magnet, whether natural

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or artificial, are merely owing to its metallic quality; and that the same effect would be produced by a simple bar of steel or iron. It consequently acts, not as a magnet, but as a metal.

The third section contains an inquiry into the connexion which may subsist between the galvanic influence and the muscular, nervous, and vascular systems of animals. The author does not undertake to enter into a minute investigation of these three subjects; but merely considers them as a convenient classification, in arranging the facts which resulted from his experiments. As the most skilful anatomist cannot succeed in completely separating the muscles from the nerves, and as he cannot consequently determine, in any given case, whether the galvanic influence has passed by the former of these systems, or by the latter, the galvanic experiments were in the present instance made on two classes of animals, which are conjectured by several physiologists to be unprovided either with brain or nerves, on account of the difficulty of discovering in them these organs. Of this description are earth-worms and leeches. On this occasion the author apprizes his reader, that his opinion is altogether different from that of the physiologists in question.

He had an opportunity to notice that the earth-worms, laid on a circular piece of zinc, dis-

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played, as soon as a piece of silver was brought in contact, contractions precisely similar to those manifested by living frogs; or, in other words, that the contractions were confined to the parts which had been previously wounded, and were in a cicatrized state. When these worms were suspended across a rod of silver, and the head and tail brought in contact at the same time, with the zinc, the effect of the galvanic influence was such as to produce a shock which extended from the tail to the head. The same experiment was tried on leeches with a similar effect. It becomes very striking when an earth-worm, or a leech, is placed on a piece of silver which rests on a plate of zinc. In this case, the animal seems to be repulsed by a painful sensation, whenever the anterior part of its body is brought near to the zinc, in the efforts it makes to repose itself. It becomes fatigued by its fruitless exertions to change this position, in which it does not appear to be retained by any visible obstacle. When it is placed on the zinc, it seems to feel a sensation of the same unpleasant nature, as soon as its head is brought in contact with the silver, in its attempts to crawl, and to extricate itself from the pain it suffers.

These facts seem to prove that the animals in question are provided with nerves; but do not demonstrate that the galvanic influence acts on

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the muscles alone, without the mediation of the nerves. The latter, indeed, appear to be more immediately concerned in all the phenomena of galvanism. On this subject our author made a very curious and interesting inquiry, namely, whether the nerves in general are equally subjected to the influence of galvanism, or whether, on the other hand, those which are governed by the will feel it exclusively. Of all the muscles, the heart is the one which is at the same time the most powerful, and the most independent of the will. This muscle, in a highly irritable state, was separated from the body of a cow which had been recently killed, and subjected, in its preparation, to the processes employed in preparing frogs. The intercostal nerve having been coated, while the contractions of the auricles were still apparent, the metals which were brought in contact did not appear to have any influence on these contractions, neither did they renew them after they had ceased. The great influence of the passions of the mind, as well as of particular injuries of the brain, on similar contractions, having led the author to presume that he ought to have found a result very different from the one which has just been pointed out, he determined to persevere in his trials; and, after a variety of useless attempts on hot-blooded animals, succeeded in renewing, by the means of galvanism, the contractile

 tractile

tractile movements of the heart of a frog, an hour after they had ceased. He repeated this experiment more than twenty times, and found it constantly to succeed. The most certain method of operating is to place the heart, in an insulated state, on a small plate of zinc. The experiment may be made, with a similar result, on the heart of a cat drowned in warm water; but when the animal has been drowned by an immersion in cold water, it does not succeed. Dr. FOWLER made several fruitless attempts to transmit the galvanic influence to kittens still remaining in the belly of the mother, after she had been killed. The stomach and intestines did not appear to him to be at all susceptible of this influence.

Its effects on the organs of the senses had already been discovered by the celebrated VOLTA; and much has been said relative to the disagreeable taste left on the tongue, when two different metals, one of them laid on the superior surface of that organ, and the other touching the inferior surface, are brought in contact. This taste is particularly striking when gold and zinc are employed. In comparing it with the one which electricity produces on the same organ, Dr. FOWLER discovered that they do not bear any resemblance to each other. The successful result of the experiments is influenced by the temperature,

rature, the most convenient one being that of the tongue itself. Within certain limits, however, the temperature appears to have no other influence than that of diminishing the sensibility of the organ in question; and in this respect either cold or heat, or, in other words, a temperature either too low or too high, is productive of the same effect, that of blunting, and even destroying the sensation, but not the cause. Irritability, properly so called, is not destroyed by cold; since we are told by Dr. Fowler, that the thighs of frogs, after having been suffered to lie for some hours on a bit of glass, still displayed powerful contractions. On the other hand, the life and irritability of the most healthy frogs are completely destroyed in a few minutes, when these animals are put into water heated to 106 degrees of Fahrenheit.

By introducing into each of his ears a different metal, and by establishing a communication between the two metallic substances, our author felt a shock in the head at the instant of their contact. He could not, by the means of galvanism, affect either the ordinary sense of feeling, or that of the smell; but the effect produced by it on the sight was very singular. He placed a bit of tin-foil on the point of the tongue, and applied the rounded extremity of a silver pencil-case to the internal angle of the eye. After

 having

having waited until the above parts were sufficiently accustomed to the contact, to enable him to perceive a sensation of some kind, he brought the tin and silver in contact, and instantly perceived a flash of pale light, at the same time that his tongue was affected by the sensation customarily produced by the contact of the two metals. Zinc and gold render the flash still more intense.

The same effect may be produced by the insertion of one of the two metals into the nose, the nasal branch of the fifth pair of nerves, which joins a branch of the third pair, occasioning a sympathy between the two organs. In this experiment the piece of zinc ought to be laid on the tongue. When it is made with the necessary precautions, the iris is even seen to dilate, and the pupil to contract, as often as the metals are brought in contact. The sensation of a flash may also be produced by a still more simple process, namely, by placing one of the metals within the upper lip, between it and the gum, and the other on the tongue, or between the gums and the lower lip. The sensation, in this case, instead of being confined to the eye, extends to every part of the face. For this experiment we are indebted to Mr. HUNTER, of York. Dr. RUTHERFORD has noticed that the sensation takes place immediately after the separation, as well

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as at the time of the contact of the metals. A kind of heat is also felt on the tongue at the same moment.

There is likewise, in the human body, a system of organs analogous to that of the nerves, so far at least as they are possessed of an indefinite ramification. These are the blood-vessels, as well those which are named arteries, and which carry the blood from the heart to the extremities, as those which are denominated veins, and which bring back that fluid from the extremities to the heart. Dr. FOWLER was desirous to ascertain whether this system, called the vascular, would be influenced by galvanism. He accordingly disposed the foot of a living frog in the same way as he would have done, had he wished to observe the circulation of the blood, that is, he placed the membrane which separates the phalanxes, in a state of extreme tension, on a microscope of strong powers. The different currents formed by the blood were to be seen very distinctly, and appeared to the author to be accelerated by each application of the galvanic fluid. The gentlemen who were present on the occasion were not, however, sensible of this acceleration. The experiment is so delicate and complicated, more particularly on account of the inflammation which the preparation invariably occasions in the parts which are subjected to it,

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that the uncertainty of its result is by no means extraordinary. On this account Dr. FOWLER had recourse to a different process. After having dissected the sciatic nerve of a frog down to the joint of the knee, he raised up and insulated, on a paper covered with wax, the crural artery, placing it in the circuit of silver and zinc. The contact of the metals was not productive of any contractions in the muscles; at the same time that a spark, or a simple current of electricity, applied to the vessels themselves, excited powerful contractions. From the few facts he was enabled to collect, Dr. FOWLER did not come to any absolute conclusion, whether the blood-vessels are absolutely insensible to galvanism, or otherwise.

He afterwards endeavoured to ascertain the direction followed by the galvanic influence, when applied to the nervous system. He found it to act as evidently in the direction by which it proceeds from the extremity of the nerves towards their origin, as in the opposite direction, namely, in the one by which the influence of the will is transmitted to the muscles that are obedient to it.

In the fourth division of his Essay, Dr. FOWLER employs the galvanic influence to determine a strongly contested point of physiology, namely, the source from whence the respective forces of the nerves and muscles emanate. While several physi-

physiologists place this source exclusively in the brain, others maintain that it resides in the arterial system, and in the fluid it contains, which, agreeably to the system of Dr. MONRO, gives the tone to the nerves, and disposes them to transmit impressions. To resolve this question, it became necessary to intercept the communication of the muscles, as well with the brain as with the arteries, and to observe the effects which would result. It is to be observed, that this interruption was to be merely partial; since, in rendering it complete, the organization would have been so much changed as to lead to an error in the result. The legs, after the sciatic nerve had been divided in each of them, became paralytic; and, notwithstanding, immediately after the operation, became violently contracted by the application of the metals. The experiment having been repeated on four frogs, killed at different epochs, namely, from two to nine days after the amputation of the nerve, it was not demonstrated that the contractile force was either more permanent, or more energetic, in the legs, the nerves of which had remained in their entire state, than in those, the nerves of which had been divided.

These experiments were repeated on frogs which had been suffered to live for a long time after the nerve had been divided, to the end that

the wound might be well cicatrized. It appeared that there had been no true regeneration of the nerve, and that the gelatinous substance which had been formed between the divided extremities, and by which they appeared to have been rejoined, was not in reality a nervous substance. The leg, the nerve of which had been divided, continued to contract longer than the other, although with less energy.

Similar experiments were afterwards made, but with a very different result. Notwithstanding the appearance of the muscles, in the limbs, the nerves of which had been divided upwards of six weeks before, was precisely the same with that of the muscles which had not been subjected to any operation, still the former, brought into a paralysed state by the amputation of the nerve, were so little acted on, either by electricity or by galvanism, that the contractions were scarcely perceptible.

Experiments, similar to those made on the nerves, were tried by our author on the arteries, with this difference, that a simple ligature was substituted to the amputation. It appeared to him, that the interruption of the circulation of the blood had been more effectual in destroying the action of galvanism, than had been that of the communication with the brain, by the means of the amputation of the nerve. As these two descrip-

descriptions of experiments had been made, however, on distinct animals, doubts remained relative to the consequences which might be drawn from a comparison between them. To remove these doubts, Doctor FOWLER dissected, in the same frog, the sciatic nerve, on the one side, and on the other tied the crural artery. At the expiration of two days the animal was killed. Within the twenty-four hours which followed its death, the leg, the nerve of which had been divided, contracted more violently than the other. After this lapse of time there did not appear to be any difference in the intensity of the contractions on either side; but at no one moment were they more violent in the leg, the artery of which had been tied, than in the one the nerve of which had been dissected.

Another frog having been treated in the same way, and killed on the sixth day after the operations had been performed, the contractions were very weak in the leg, the artery of which had been tied, and ceased entirely at the expiration of twenty-two hours after the death of the animal. In the leg, however, the nerve of which had been divided, they seemed as powerful as they usually are in a leg which has not been subjected to such a process; and the sensibility to the galvanic influence lasted upwards of two days beyond the epoch at which it ceased in the

other

other leg. These experiments having been repeated on three other frogs, were attended by the same result, and left no doubt but that the interruption of the circulation of the blood, brought about a proportionate diminution in the sensibility of the nerves and muscles to the galvanic influence.

It was necessary to ascertain whether this proportion would hold good in all the gradations, that is, whether an increase in the arterial action would produce an augmentation in the galvanic sensibility. An inflammation of any part whatever is constantly accompanied by an acceleration in the motion of the blood: our author accordingly produced an artificial inflammation in one of the legs of a frog. By the application of the galvanic process contractions were produced in this leg, but not on the other, which was left in its entire state. The same thing happened in the case of another frog, during two consecutive days after its death. Five other experiments were attended by a similar result. Dr. FOWLER explains the difference between these uniform consequences, and those of the two experiments in which the faculty of manifesting contractions appeared to have been destroyed by the amputation of the nerve. He entertains a persuasion that, in the latter case, several of the arteries which proceed to the nerve, and accompany it in its

its ramifications, had been cut as well as the nerve itself, and had thus essentially changed its organization.

Here Dr. Fowler combats the opinion of Fontana, that the nerves are never re-established, after having been divided, in such a way as that the intermediate part should become a truly nervous substance. In opposition to this opinion, he cites the experiment made by Dr. Monro, in which the sciatic nerve of a frog was found to have been completely re-produced at the expiration of a year after it had been amputated. The system of the re-production of the nerves is supported by the case of the captain of a ship, who, in consequence of a gun-shot wound, lost the use of his arm, the ball having divided a branch of the cervical nerves; but who recovered the use of the limb at the end of two years and a half*. From the above series of facts, Dr. Fowler concludes, that the arterial system contributes more essentially than the brain itself, to stimulate and keep up the disposition of the muscles and nerves to the galvanic contractions.

By the conclusions and inferences he had drawn, Dr. Fowler was led to a series of very

* This question has been fully resolved by the experiments of Dr. Haighton and Mr. Cruickshank, inserted in the Philosophical Transactions for 1795.

ingenious

ingenious experiments, intended to ascertain what reliance is to be placed on the opinion of FONTANA, JOHN HUNTER, and other physiologists, who ascribe to the blood a particular kind of vitality, on which the narcotic poisons, and opium more especially, have a very powerful effect; at the same time that they scarcely act on the muscles and nerves, properly so called, and considered to be independent of the blood by which they are nourished. The experiments made by FONTANA in support of this opinion, are almost innumerable.

Our author made a very strong solution of opium in water, and after having made choice of two frogs possessing an equal energy, he deprived one of them of the whole of its blood, by opening the principal veins and arteries, and substituted to this fluid an injection of water, to which he added forty drops of the above-mentioned solution of opium. In treating the other frog, he injected into its blood, by the means of an incision made in the heart, the same quantity of opium. The former of these animals was deprived of its irritability an hour sooner than the latter, more than a day before which it ceased to be sensible to the galvanic influence. The experiment was afterwards diversified in the following manner. Two frogs having been previously killed, thirteen drops only of the solution of opium

opium were substituted to the blood, in the case of one of them, and in that of the other, an equal quantity was mixed with the blood itself. The instant the injection was made, the heart of each of the frogs became white, and lost its irritability. At the expiration of forty-eight hours the former of these animals became nearly insensible to the galvanic influence, while the latter still manifested powerful contractions on the plate of zinc. After seventy-two hours the galvanic contractions ceased in the instance of the former, but were still powerful in the case of the latter. Finally, at the expiration of ninety-six hours the former was in a state of putridity, at the same time that the legs of the latter were still sensible to the galvanic influence.

After having multiplied these experiments, and given them every variety of which they were susceptible, Dr. Fowler proceeds to observe, that the conclusion drawn by Fontana, from his numerous experiments made with opium, that *the circulation of the blood and humours, in the animal system, is the vehicle of opium, and that, unless for this circulation, it would not have any action on living bodies*, is diametrically opposite to the one he thinks himself warranted to draw from the experiments above cited. His opinion is founded on the following reasons:

1st, That the parts which had been the most

powerfully

powerfully acted on by the solution of opium, were not those in which the circulation was the least disturbed, but those in which it had been almost entirely intercepted.

2dly, On two limbs in which the circulation remained equal and entire, the action of the opium was rendered unequal by the interruption of the communication of the nerves of one of them with the brain, at the part where the opium had been applied.

Dr. Fowler brings forward, in his appendix, several insulated facts which presented themselves to him in the course of his experiments, and which are not devoid of interest. He remarks:

1st, That the presence of the skin preserves for a long time the galvanic sensibility of the muscles, when plunged in water; and concludes from hence, that this fluid does not transude through the pores.

2dly, That the effect of galvanism is very different, when it is applied to a particular nerve, or, on the other hand, to the brain, or spinal marrow. In the first instance, all the muscles to which the nerve is distributed feel the contractions. In the latter, none of the muscles are brought to act, except those which derive their nerves from the part touched in an immediate way by the metals.

3dly, He considered himself authorized to conclude,

clude, from several experiments he made with the electrophorus, that the galvanic influence has no connexion whatever with electricity.

At the close of Dr. Fowler's work a letter is inserted, from Professor Robison, of the University of Edinburgh, which contains several curious experiments on the galvanic influence, nearly the whole of them made on himself. For instance, by applying one of the two metallic substances to a wound which he had accidentally received, and likewise to the nerve of a carious tooth, he felt this influence in a very sensible manner. He formed a kind of galvanic battery with pieces of silver and zinc, disposed alternately over each other; and having applied the side of this aggregation of metals to the tongue, experienced a very disagreeable sensation. He discovered, by their taste, the solders in gold and silver trinkets. He proved, by a very curious experiment, that the galvanic sensation may be felt when the metallic substances are placed at a certain distance from each other. To effect this, he put a piece of zinc between one of the cheeks and the gums, and a piece of silver on the opposite side within the other cheek. Having introduced a rod of zinc between the piece of zinc and the cheek on the one side, and a rod of silver between the silver and the cheek on the other, he afterwards carefully brought into contact the extremities of the

two rods withoutside the mouth, and felt a powerful sensation in the gums. The moment before the contact he perceived a flash, and felt the same sensation when he again separated the extremities of the rods, as soon as they were brought to a small distance from each other. When he stationed the rods, or wires, in such a way as that the silver should touch the zinc, and *vice versâ*, he could not perceive any galvanic effect. He was enabled to produce the sensations noticed above, by simply bringing together the metals placed to the right and left on the gums, which he was cautious, however, not to press too much.

M. Humboldt, whose galvanic inquiries we shall have occasion to notice more particularly hereafter, having found, that when the galvanic circle was disposed in the following manner, namely, the nerve, zinc, gold, zinc, and the muscle, no signs of movement were manifested; but that the movements were produced the instant the zinc was moistened by the breath:—and having also observed, that the influence in question furnished a mode of ascertaining, in any given substance, the presence of the minutest quantity of charcoal, Dr. Wells, in his paper on galvanism, contained in the Philosophical Transactions for 1795, notices, that he had obtained

tained the same results. The latter, however, in the experiments he made, was induced to limit to charcoal newly made, the faculty of conducting the galvanic influence. He found that a single metal, when perfectly pure and free from alloy, was incapable of producing contractions; but that by gently rubbing one of its sides on tin, silk, wool, fish-skin, the palm of the hand, sealing-wax, wood, marble, &c. the contractions might be produced. It should be noticed here, that it is not to common electricity that these phenomena are to be ascribed; seeing that the rubbed metal does not give out any sign of such electricity when the most delicate electrometers are employed. The effect is augmented by humidity; but this is not the case when the metal is insulated. The contractions are not to be produced by touching the nerve alone; but, on the other hand, it is necessary that the nerve and muscle should be touched at the same time. The rubbed metal retains the power for a whole day, even after having excited nearly two hundred contractions.

In announcing his opinion that the galvanic effects are not owing to the ordinary and known modifications of electricity, Dr. Wells appears to be, notwithstanding, of opinion, that the active principle is the electric fluid. He presumes that,

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by friction, the nature of a metallic substance, relatively to electricity, is changed, and the equilibrium of the electric fluid disturbed, insomuch that the metal, rubbed at one of its sides, performs the function of two different metals. He grounds this supposition on two facts, one of which is, that if the two sides, or extremities, of the metal, are rubbed, the effect is considerably diminished, insomuch that, in such a case, it often happens that the contractions do not ensue. The other fact which he adduces is, that if the nerve and muscle are coated with a metal differing from the one which has been rubbed, whenever the latter is applied to the coatings, the contractions cannot be produced, either by touching the metals, or by separating them.

The hypothesis adopted by VOLTA and several other physiologists, that the metallic contact produces a change in the disposition of the electric fluid, is combated successfully by Dr. WELLS, who very shrewdly asks why the natural moisture of the animal does not admit a communication between the two metals, previously to their being connected by any other conductor? In the cases of the effects produced by charcoal, he proves, by several experiments, that the electricity is not communicated to that substance by friction, any more than it is to metals. He therefore conjectures

tures that an incipient oxydation, or some other chemical change, must be induced on the surface of the above substances. He is decidedly of opinion that the galvanic phenomena are electrical, the influence being conducted by all the conductors of electricity, and by no others.

CHAP. VII.

Irritability of the vegetable fibre—On animal heat and vitality—Distinction between irritability and sensibility.

BEFORE the reader enters further into the history of galvanism, it appears necessary, to give him a more correct and clear idea of its nature, to devote a particular chapter to the subjects announced above. As a proof that they contribute essentially to the right comprehension of the galvanic phenomena, it is certain that almost all the writers who have treated this subject, have dwelt on them with more or less earnestness.

In the course of his experiments made in the winter of the year 1793, M. HUMBOLDT fell on a discovery relative to the irritability of the vegetable fibre. This discovery he followed up so successfully, as to be enabled, on his return from Geneva to Germany, to apply it to the animal organization, and to illustrate it by several interesting details. The surprizing effects of the metallic oxydes, of the vital gas, and of water even, on animated matter, together with the great phenomenon of respiration, and, more particularly

ticularly the very ingenious ideas developed by M. GIRTANNER on the subject of oxygen, considered as the principle of the irritability of all organized matter: these different considerations induced M. HUMBOLDT to make inquiries after a substance with which the oxygen would be so feebly united, as to be disengaged from it with facility. He was persuaded that a substance of this nature would lead him to experiments of infinite utility, and would enable him to augment, in a perceptible way, the irritability of the animated fibre. His earliest choice fell on the oxygenated muriatic acid gas, mixed with water. The bases of the above fluid display so feeble a reciprocal action to each other, that the oxygen is disengaged by the mere stimulus of light.

The attention of M. HUMBOLDT was, in the first instance, directed to the vegetable fibre; but the striking analogy which subsists between the two kingdoms of organized nature, and the opinion he entertained that the muscular fibre is the same both in animal and vegetable substances, stimulated him to direct his experiments to the former. Having been for a long time engaged in noticing the phenomena of galvanism, he perceived in them an excellent mode of ascertaining the degree of irritability inherent in an animal. He took the thigh of a frog (*rana esculenta* L.) the crural nerve of which had been armed with

zinc, and irritated by a conductor of silver. The limbs had been so much fatigued for the space of three hours, that the slightest movements only were perceptible. It was altogether free from contractions; insomuch that gold and zinc, which are considered as the most active metals, merely produced a feeble movement in the *gemellus* muscle. This animal's leg therefore appeared to M. Humboldt to be extremely well calculated for decisive experiments.

He accordingly moistened the crural nerve with water strongly impregnated with the oxygenated muriatic acid, and, having laid the limb on zinc, touched the above nerve, and the muscles, with a conductor of silver. He was, as must necessarily be supposed, not a little surprized when he perceived that the leg of the frog, exhausted as it had been by the preceding operations, displayed spasmodic contractions from one extremity to the other, and became so violently convulsed as to throw itself from off the zinc. He instantly had recourse to comparative experiments, which he properly considers as the only bulwark which can guard the naturalist from falling into error. He took three thighs of frogs (rana *temporaria* L.) which had been galvanised for the space of four hours, and the irritability of which was extremely weak. He placed the crural nerves of these animals in three vessels filled, two of them with pure

water,

water, and the third with the oxygenated muriatic acid. The results of these experiments, which were frequently repeated, were as follows: In the former of the nerves, movements were excited somewhat more powerfully than before. The second became almost insensible to galvanism. But the faculty of production was surprizingly augmented in the third, which displayed such violent muscular contractions, that the spectators might have supposed the animal to have been recently killed, and in the enjoyment of all its natural vigour.

This experiment proves, that the oxygenated muriatic acid acts on the nervous fibre merely by the means of the oxygen it disengages. The increase of irritability induced by this acid, does not last for more than from five to eight minutes, at the end of which lapse of time the muscular force becomes less than before the humectation. The oxygenated muriatic acid appears at length to have been converted into the common muriatic acid, which is highly destructive of irritability. The observer might, at a first view, be led to think that the debility which follows is the effect of excessive irritation, or, in other words, that it is what is called by Dr. Brown, *indirect debility*. This is not, however, the case, since, as soon as the nerve in question is again moistened with the oxygenated muriatic acid, it will excite pow-

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erful muscular contractions the instant it is coated with heterogeneous metals. Now, it would be impossible to remove an indirect debility by *sthenic* remedies. It would appear, on the other hand, that this fresh humectation augments the irritability in no other way than by restoring to the organ a new portion of oxygen.

According to HUMBOLDT, the effect of the oxygenated muriatic acid on the heart, produces a very singular phenomenon. He made an experiment on the heart of a frog which had ceased to palpitate. The irritability of this viscus was annihilated to such a degree, that mechanical *stimuli* no longer produced in it any movement. He took it between his forceps, and threw it into a glass filled with the common muriatic acid; but in this state it did not manifest any sign of irritation. Scarcely, however, had he thrown it into the oxygenated muriatic acid, when it began to palpitate, until at length the palpitations were augmented in a very powerful degree. Having laid it on a board, the movements, which continued for the space of five or six minutes, gradually ceased; but were again re-produced by a fresh humectation with the oxygenated muriatic acid.

The following is another experiment which M. HUMBOLDT never found to fail. Having kept the leg of a frog in a solution of opium for

the space of twelve minutes, at the end of which time its irritability was so completely destroyed, that galvanism was incapable of producing in it any movement, he had recourse to very strong muriatic acid, and having washed the limb with it, in two minutes the irritability of the fibre was restored, and very powerful contractions produced in the muscles. This experiment, when repeated on mice, was attended by a similar result. Animals with hot blood are not less sensible to the effects of oxygen than cold-blooded animals.

The phenomenon of the conversion of oxygenated muriatic acid into simple muriatic acid, as well by the vegetable as by the animal fibre, evinces, more strongly than any other phenomenon, the following facts.

1st, That the augmentation of irritability is the result of a nice combination of the oxygen with the animal organs.

2dly, That, however different the elements of the animal fibre, and those of the vegetable fibre, may appear to be, both of them follow, notwithstanding, the same affinities, and are excited by the same stimulus of the oxygen.

3dly, That the chemical process of vitality is a process of slight combustion; and that, as was very justly observed by M. Reil, a learned physiologist of Halle, in a letter addressed to M. Hum-

M. Humboldt, the combustibility of a dead substance resembles the irritability of organized matter, each of them depending on their affinity with oxygen, and both of them producing a disengagement of caloric. In expatiating on this subject, M. Humboldt gives it as his opinion, that the oxygenated muriatic acid, neutralized by soda or potash, would furnish a very interesting object to pharmacy.

An inquiry into animal heat, and its different relations, followed by a new explanation of the calorific phenomena, and an investigation of the opinions of different modern authors on that subject, has been lately published. The following is a concise analysis of this work, the production of M. Josse, of Rennes*.

This author, after having examined what ought to be understood by light and caloric, lays down the principles of the new system he has adopted relative to the latter, and its different modes of action. According to this system, he considers caloric to exist in all bodies, and to be constantly in the states of combination and non-combina-

* For a more perfect understanding of this and the other subjects treated in the present chapter, reference may be had by the reader to the authors who will be occasionally cited, and the analyses of whose works would carry us beyond our necessary and prescribed limits.

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tion. In the former of these states it is *latent* and insensible, without any influence on the temperature of bodies, but governing entirely their more or less solid fluid, or gaseous state. In the latter state it is found between the particles of matter, and is consequently free in their interstices, as well as sensible and thermometrical, contributing nothing to the solidity, fluidity, or gaseity, of bodies, but having an entire influence on their temperature. The conclusion he draws from hence is, that solids do not become liquids or gaseous fluids, unless by the quantity of caloric combined in them; and that, consequently, a sensation of cold is occasioned by the passage of free caloric, in the combination in which it remains latent; at the same time that, by an inverted mode of reasoning, the passage from a fluid to a solid state is merely due to the successive loss of caloric, which, in quitting the mixed state, and entering into that of combination, becomes latent. A loss of such a nature must necessarily produce heat, by the liberation of the combined caloric.

In applying these general principles to animality, our author demonstrates, with considerable ingenuity, the mode in which heat ought necessarily to be produced in animals. He examines its relations with the digestion, as well as with nutrition; and, in a physiological discussion on

the blood and respiration, endeavours to refute the generally received opinion relative to the dis-hydrogenation and decarbonation of the blood in the lungs. His aim is to prove that the water and carbonic acid, the existence of which has been ascertained in expiration, do not arise from the above changes and modifications of the blood in the lungs, but, on the other hand, from the pulmonary transpiration resulting from the completion of the functions of those organs.

After having specified what these functions really are, our author considers the influence of the different temperatures on animated beings, and the effects which result from them by the action of caloric on the substance of fat, relatively to nutrition and transpiration. In the latter part of his work he gives new demonstrations of his theory, discussing, at the same time, the opinions of Blumenbach, Brisson, and Fourcroy. The consequences he draws from the principles he lays down, are extremely useful to him in the explanation of several of the phenomena which have occupied the researches of so many physiologists.

It will here be proper to introduce a few reflections on muscular contraction, and on the distinction between irritability and sensibility.

It is certain that the contraction of the muscles does not arise from a mechanical cause. The augmen-

augmentation of the cohesive force, and the greater durity of the muscles, when contracted, appear to leave no doubt on that head. The causes of the contraction may be divided into external and internal; and may be denominated elective or habitual *stimuli*, which the nerves distributed in the muscles obey, without being on that account the sole principles of vitality. This is evidenced by the monsters which have a living existence, although born without a brain, and without nerves*. Now, does not the existence of animals without these parts, evidently prove that there is a principle of life distinct from the nervous principle, and totally independent of the sensation, and of the perception of sentiment? HALLER was the first physiologist by whom animals of this description were noticed; and their very peculiar organization has been since explained by JOHN HUNTER. The latter has, indeed, manifested an opinion, that the stomach is a centre, or seat of life, more essential than the brain.

* See a Latin dissertation by Dr. LUD. ROGER, published in 1760, entitled,—Specimen physiologicum, de perpetuâ fibrarum muscularium palpitatione, novum phenomenum, in corpore humano, experientiis detectum et demonstratum.—Gottingæ.

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What is, at the least, certain on this head, is, that life may be extinguished in an immediate way, and more completely, by a powerful percussion on the stomach, than by a similar one on any other part of the body*. It is besides well known, that the muscular fibres of animals endowed with a nervous system, preserve their irritability for a considerable time after they have been separated from the brain and nerves. The phenomena of vegation have made it equally evident, that irritability may exist in nature without sensation, without perception, and without any suspicion of the existence of a nervous system.

* When the percussion is followed by such an effect, ought it to be entirely ascribed to the percussed stomach, when it is considered that this viscus is susceptible of a displacement in the abdomen, and that, before it can be reached by the percussion, the latter must have operated powerfully, both on the integuments, and on the muscles by which the stomach is covered? When, in this region, the percussion goes so far as to extinguish life, is it not rather because its action is directed to the nervous centre of the diaphragm, the sensibility of which is so great, that the smallest excitement, from whatever cause it may arise, agitates and deranges it, producing a difficulty of respiration? It is true that, under these circumstances, the disturbed state of the respiration is momentaneous: were it, however, to be continued for a sufficient length of time, it would be capable of extinguishing life. This is unquestionably the reason why several philosophers have assigned to the nervous centre of the diaphragm the seat of the soul.

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The perceptible movements of the sensitive plant are a proof of this, as are also, more particularly, the movements which must necessarily take place in plants of every description, in the progress of their developement. Seeing that the growth of the solids cannot be accounted for by the circulation of the sap which distributes the nourishment, it is necessary to have recourse to some other power, which may act by laws different from those of dead matter. In favour of this opinion it ought, moreover, to be observed, that the animals deprived of the brain and nerves, are of the class of *vermes*, the most simple in nature; and that they have but one sole function, that of assimilation :—a function which does not require the variety of action, and peculiar perceptions, necessary to animals of a more complicated organization.

The state of the egg, before incubation, and the condition of the animals, which, having been thrown into a torpid state by the cold, afterwards recover their vitality, present us with facts favourable to this opinion, insomuch as they prove, that there is a certain innate vital principle of conservation, independent, not only of the operation of the nervous system, but even of the circulation. It should be observed that, in this state of repose, the above portions of animal matter are preserved much longer from corruption, than they would be

be without this conservatory principle; and that their fluids are secured from congelation, under the circumstances of a degree of cold which would have converted them into ice, had they been deprived of every principle of life. Let it be noticed here, that, in addition to muscular irritability, the principal powers of simple life, if not the only ones, consist of the assimilation of the aliments, and of the faculty which, in living bodies, preserves them from putrefaction.

After reasoning has been employed, experience presents itself, to prove clearly that vitality is independent of the nervous power. When the trunk of a nerve has been divided, the limb of which it constituted a part, although deprived of every sensation, and of every voluntary motion, continues, notwithstanding, to be exempt from spontaneous putrefaction, and still preserve its heat for a long time. The only apparent and visible change it undergoes from the separation, is the atrophy into which it falls some time after.

To go still further, and demonstrate that there are circumstances which seem to prove, not only that the nervous system is merely appendant to life, but also that it tends to prevent the operations resulting from it, and to abridge its existence. It is, in the first place, a certain and acknowledged fact, that simple life survives sensation much longer, if the death of an animal is brought

brought about by the destruction of the nervous system, than if it sinks under hemorrhagy, suffocation, or any other violence. Another curious and well-established fact is, that when a fish, instantly after being taken out of the water, is killed by a violent blow on the head, by which the skull is fractured, the irritability and flexibility of the muscles are preserved much longer than they would have been, if it had been allowed to die with the organs of sensation in an entire state. So very sensible are the fishermen of this, that they have recourse to the above practice, with a view to render the fishes they catch, susceptible for a longer time to the operation called *crimping*. Salmon is one of the fishes the least tenacious of life, insomuch that, after having been taken out of the water, it will cease, in less than half an hour, to manifest any sign of vitality, provided it be not exposed to any violence. But if, on the other hand, it receives, as soon as it is caught, a violent blow on the head, the muscles will continue, for the space of more than twelve hours, to exhibit visible signs of irritability.

In the majority of animals with hot blood, a phenomenon has been remarked which seems to depend on the same principle. It has been proved that a violent exertion of the voluntary movements, immediately before death, prevents the

muscles, as soon as they are cold, from becoming stiff, and augments their tendency to putrefaction. Thus, in the case of an ox being slaughtered after having been exhausted by fatigue, the limbs, in proportion as they become cold, will not be stiffened, and the flesh of an animal, under these circumstances, cannot be preserved by the means of salt. The facts which have been thus stated, are, however, liable to contain modifications.

In confirmation of the principle which has been established, it ought to be observed that, in certain diseases which afflict humanity, there is a symptom which proves that the digestion, one of the principal functions of simple life, or animality, is sometimes better performed than heretofore, after the brain has received particular injuries. It has also been remarked, that in certain diseases, such as the hydrocephalus, and the apoplectic paralysis, in which the exercise of the senses is in a great measure suspended or destroyed, it frequently happens that the appetite and digestion are better than in health.

From these facts, we may conclude with Mr. John Hunter, that the exercise of the sensations is, in general, injurious to life, seeing that it is accompanied by a kind of fatigue; and that this is also the case with voluntary motion:—insomuch, that the whole of the correspondence which

which is kept up by the medium of the nerves, whether the communication be made to the brain, as in the case of the sensations, or emanates from the brain, as in the case of the voluntary acts, contributes to exhaust the animal forces. As an internal and long-continued reflection, although it may not be followed by any external act, tends to produce an inaptitude for any other exercise, it would appear that the brain, or *sensorium commune*, as it has been called, is the organ more especially subject to the kind of suffering denominated *fatigue*. One of the inferences which may be drawn from these facts, is the necessity of sleep, which consists in a momentaneous suspension of the sensations, volition, and thought. It is a resource resorted to by Nature, to enable the powers of life to re-establish themselves, after the vital energies have been exhausted by fatigue.

At a time when so successful a progress has been made, in the discovery of the real principle of irritability, it is of some importance to explain the properties of this faculty of living bodies, and to distinguish it from sensibility. Irritability is the property by which a muscular part contracts, when irritated. Sensibility is the quality by which a body receives sensations. The nerve does not contract when it feels, and a muscle does not always feel when it contracts. Spasm is an ex-

cess of sensibility, and atony its defective state. Eretism, or the violent tension of the fibres, is the excess of irritability, and relaxation its exhausted state. Far from irritability and sensibility being one and the same faculty, it has been demonstrated that, in living bodies, the increase of the one is almost invariably attended by the destruction of the other. It has been presumed that irritability exists in several living fluids; and to this cause has been ascribed the congelation of the blood, of the white of an egg, and of lymph. To the destruction of irritability, in living fluids, by a powerful excitation, the putrefaction which is manifested, on the introduction of a very acrid substance, has been ascribed.

The following researches on vitality, accompanied by several galvanic experiments by M. Sue, of the Faculty of Medicine of Paris, are illustrative of the subjects already treated in the present chapter.

In speaking of the discoveries relative to the nerves, this author observes, that the efforts hitherto made have afforded but little information respecting the nature of the nervous fluid; insomuch, that it has not been ascertained whether this substance, by which the nerves appear to be filled, possesses a circulatory movement. He brings forward several observations, to prove that the brain is not invariably the seat of sensation, which

which must consequently exist elsewhere in animals born without that viscus, as well as in those in which an ossification has taken place. From the numberless experiments of FONTANA it would appear that, under these circumstances, the sensation must be seated in the spinal marrow; since, without this supposition, it would be impossible to explain the phenomena of vitality and sensibility, noticed in animals born without the brain.

It has been proved by several experiments made by M. SUE, with a view to ascertain what happens to certain particular animals after the head has been cut off, that the nerves are endued with a kind of action, which continues for a long time after the parts to which they belong have been separated from the body; and that, after this separation, the movements of the parts in question may be animated in the most sensible way. This property renders organized bodies very different from machines, to which they have been so often compared. Our author demonstrates that the structure of the organs essential to life, or constituting vitality in certain animals, have been very improperly considered as belonging to all; seeing that the *polypi*, and several other animals, do not perish, notwithstanding they have been subjected to certain operations and divisions, which, in other animals, are attended by the destruction of life. The simple mode of the

re-production of the polypus, he observes, throws a greater light on the variety of means employed by Nature, and on her resources in the organization of living matter, than a multitude of isolated reasonings, which are not founded on observation.

The experiments of M. SUE were made on different animals, with a view to ascertain the duration of the vital power in the nerves and muscular fibres, whether it results from spontaneous effects, or from excitements produced by the contact of metallic substances. These experiments were made on various animals of different sizes, by the separation of the head from the body. In all of them vitality was prolonged, for a longer or shorter duration of time, after the separation had taken place. The head and the different parts of the body, more particularly the heart, still preserved their movements; and the irritated muscles manifested contractions in a greater or less degree, and convulsive motions proportionally violent. The decollation of two calves was attended by very singular phenomena.

Several of the experiments had for their object, the demonstration of the effects of galvanism. A small frog having been immersed in the muriatic acid gas, appeared to be dead at the expiration of a second of time; but on being taken out of the gas, and thrown into water, in-

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stantly began to move. This demonstrates the influence of the muriatic acid on the respiration of the animal. The same frog, after its movements had ceased, having been thrown into oxygen gas, and kept in it for the space of two minutes, did not manifest any faculty of motion. An excitement having been produced on the crural nerve of the right extremity, by the means of a silver thread passed under the nerve, and brought in contact with zinc, movements were gradually perceptible, in the first instance throughout the length of the extremity, and afterwards in every part of the frog on that side. These movements, which were invariably on the same side, were augmented in the upper extremity, by changing the disposition of the coating, and placing it towards the middle and anterior region of the spinal marrow, &c. &c.

This experiment having been repeated on several animals, sometimes towards the middle region of the nerves, and at others towards their extremities, the movements were invariably more violent when the points of the coating were placed at the extremities. This fact is in favour of the opinion of VALLI, who presumes, that the sensibility is augmented in proportion as the excitements are brought towards the extremities of the nerves; and diminished when a contrary direction is given to them.

The crural nerve of a frog having been bound, as

as well at its origin as at its extremity, by a very fine waxed thread, and an excitement established between the two ligatures, by the means of silver and zinc, powerful movements were excited in all the parts of the extremity. A proof was thus obtained, that the ligatures do not prevent the action of the metallic current.

Several phenomena, equally singular in their nature, were noticed in a frog divided transversely in three parts; and in another frog, divided in the same direction, between the lower part of the lumbar region, and the upper part of the sacral. In two of the experiments, a carp and an eel were divided vertically; and, as soon as each of the divisions had been excited by coatings similar to those which had been employed in the transverse section of the frog, the movements became very violent, and were of a considerable duration. After a transverse section, in the first instance of two portions, and afterwards of three, of two fishes of the above descriptions, the trunk of the head of the carp continued to move and contract for the space of an hour and a half, without any excitement; and the head of the eel, during three quarters of an hour. The slices of the body of each of them preserved their movements during twenty minutes; and those of the tail, more than half an hour. These different movements were excited at intervals; and the vital powers were constantly renewed by the processes of

of galvanism. Three hours after the excitement, its effects were still visible.

Our author regrets that he had not time to make a particular experiment, namely, to establish a battery of the nerves of living animals, of the same species, pretty nearly of the same size, and having the parts in question as much as possible of the same volume. Beneath these nerves it was his intention to have placed a coating of lead or tin, to be brought in contact with zinc, so as to ascertain whether a coating of this nature, thus communicated, and the assemblage of nerves, would augment the effects produced by the galvanic current. The same experiment, he observes, may be tried with the nerves of living animals of different kinds.

In the above cited experiments the metallic media were constantly varied, and the following metals employed:—iron, lead, arsenic, plumbago, antimony, platina, zinc, and gold. For this purpose exciting arcs had been made, of different forms, of all the above cited metallic substances.

CHAP.

CHAP. VIII.

Review of the different theories and opinions relative to galvanism, up to the commencement of 1798.

AT the above period two Latin Dissertations on the subject of galvanism, were published by M. REINHOLD, of Magdebourg. Notwithstanding they are posterior to the researches of VOLTA and other naturalists, an extract of them is given in this place, because the author enters into a detail of all the publications which had then appeared, followed up by remarks and criticisms on each. The reader will thus be enabled to form a judgment of the merit of the different writers who had treated this very interesting subject up to the period in question.

The author sets out by remarking, that the sciences of chemistry and physiology had begun to make a very considerable progress, and were already brought to a high degree of perfection, when the celebrated GALVANI flattered himself he had made the discovery, that the cause of irritability and sensibility exists in an electricity inherent in animals. This had been no sooner announced to the public, than several naturalists

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and physiologists, led away rather by the novelty of the subject, than persuaded of the truth of the doctrine laid down, entered into a strenuous support of the experiments of GALVANI, and of the theory he had founded on them. Other naturalists, after having repeated these experiments carefully, and added others of their own, corrected the former, but at the same time rejected and endeavoured to overthrow the theory on which they were founded.

In England, Italy, and Germany, the new doctrine of galvanism had, more particularly, its partizans and opponents. Both the parties seemed to be agreed in the support of the discovery of GALVANI, but differed altogether in the explanation of the cause of the phenomena it presents. While, by some, this cause was referred to artificial electricity, that is, to an extraneous electricity transmitted to the parts of the animal; others ascribed it to an innate electricity in the parts themselves; others, again, to the escape and decomposition of the elements supplied by the antiphlogistic theory of chemistry; and others, lastly, to a certain fluid hitherto unknown. The latter of these physiologists were not agreed among themselves, some of them contending that the newly discovered fluid was a kind of electricity; while the others asserted that it was of a nature altogether different.

This diversity of opinions principally arose, according to REINHOLD, from the following causes: In the first place, several of the naturalists referred to, without waiting for the information which would have been derived from a sufficient number of experiments, had been in too great haste to establish a theory. Secondly, other naturalists, delighted with the phenomena they observed, maintained that their observations and experiments could be attended by no other result, than the one which was conformable to the hypothesis anterior to the experiments themselves. Thirdly, and lastly, another class of naturalists, having too much confidence in their own experiments, and in those of their co-operators, did not employ all the scrupulous attention by which the true observer is characterized.

In proportion to the variations in the state and temperature of the atmosphere, and to the differences in the nature of animals, the observer ought to vary his method, and the means he employs in his experiments, to obtain a satisfactory result. Many things may otherwise readily escape his attention, and contribute to change the nature of the processes he employs. He alone who, with facility and certitude, explains the whole, or the greater number of the phenomena he has noticed; who is supported by a sufficient number of experiments, well made, and

and differently combined; who has carefully noticed every fact; and who is acquainted with the laws which may, with prudence and precaution, be deduced from the assemblage of facts; may be truly said to have established a solid and rational theory.

In conformity to these principles the question of galvanism is discussed by REINHOLD, who has connected with the labours of others many interesting observations made by himself. For the sake of perspicuity, he divides the substance of his two Dissertations into eight sections.

In the first section he gives his reasons for adopting the denomination of *galvanic fluid* in preference to any other; and, having detailed all the works which had been published on galvanism, explains the order he means to follow in treating that subject.

Relatively to the denomination, he considers that all those which had been heretofore employed are insignificant and inexact. He prefers that of animal electricity to that of metallic electricity, employed by VOLTA, because the same phenomena may be produced without having recourse to metals. That of metallic irritation, proposed by CREVE, does not appear to him to have been judiciously adopted; and he is still more adverse to the hypothesis of CARRADORI, by whom the cause is denominated the *nervous fluid*,

fluid, as well as to the *influence* of FOWLER. He lays it down as a certain principle, that GALVANI and VOLTA are the authors and parents of this doctrine; seeing that they have discovered the forces of the galvanic fluid, the former in the movements it excites, and the latter in the sensations which result from it. There can be no doubt but that the phenomena of galvanism were totally unknown before their time.

As, however, it might have been urged to REINHOLD, that in the works of several learned physiologists, passages are to be found which refer to the electric phenomena observed in animals, and that these passages may have led to the discovery of galvanism; he examines several of them, extracted from the more modern authors, purposely omitting what is scattered in the works of the ancients, and which merely shows, that they had observed in animals, after their death, some vestiges of the vital force.

Prior to the discovery made by GALVANI, VASSALLI suspected that Nature had bestowed on animals electric forces, distributed in each part, and employed by them in the exercise of their functions. Having afterwards made several experiments on this subject, he added, that the electric forces he had pointed out, resembled the phenomenon of the Leyden phial. GARDINER, in his Observations on the Animal Economy,

nomy, maintains that there is in animals a vital principle, distributed in the brain, cerebellum, and medullary substance; of which principle the nerves are the conductors. He adds, that this fluid is extremely subtile, and that, instead of its being contained in the vessels, it adheres to the solid substance of the nerves. LUGHI has observed that, without deviating from the right mode of philosophizing, he considers himself authorized to conjecture, that the electric fluid, distributed widely and at intervals, is determined by the nervous fluid secreted in the glands of the brain, to the nerves themselves, where it aids sensation and motion. The opinion of KLUGEL is pretty nearly the same. GARDINI, in his publication on the influence of atmospherical electricity on vegetables, relates an experiment very similar to those of galvanism. "Lizards, he observes, after the head has been cut off, move, raise themselves up, and support themselves on their feet. This is more easily effected by laying one of these animals on a bit of glass, and bringing an electric substance in contact with its neck, at the same time that the experimenter places his finger on the tail."

The above cited authors are all of them anterior to the discovery of the doctrine of animal electricity. It is extremely probable, that if they had followed the indications pointed out to them

by their observations and experiments, they would not have been at a loss to discover the effects of galvanism. It has been already noticed that, prior to the researches of VOLTA, SULTZER had observed the effect of the application of different metals to the tongue, in the production of a certain taste, similar to that of vitriol of iron.

After having given an account of the writings of GALVANI, and of the Italian and German authors already mentioned in this work, REINHOLD dwells with much pleasure on those of VOLTA, whom he entitles the *prince of Italian naturalists.* At the commencement, the latter was attached to the theory of GALVANI, which he, notwithstanding, combated in a certain degree, and corrected several of its dogmas. He afterwards abandoned this theory by degrees, until at length he established a new one, founded on very ingenious experiments made on animated bodies. ALDINI, nephew to GALVANI, defended his uncle's theory, in two Latin dissertations, which contain several very curious experiments: it would appear, however, that these two publications, as well as another written by him in the course of the same year, in the Italian language, did not meet with the favourable reception they merited.

The researches of VALLI experienced a better fate. Having made the cause to reside in the parts of

of the animal organization, he examined the influence of the medicaments denominated by physicians *heroical* and *poisons*, on the animals which were to be subjected to galvanic experiments.

After having detailed the observations and experiments of FONTANA and BERLINGHIERI, REINHOLD proceeds to the researches of the English and French physiologists on galvanism. He here takes occasion to pay a handsome compliment to our countrymen, who, he observes, have been infinitely more industrious than their Gallic neighbours, and have opened a more extensive and more fertile field of investigation, as is proved by their publications, in which the names of MONRO, FOWLER, ROBISON, CAVALLO, WELLS, &c. shine conspicuously. Adverting to Denmark, he cites the names of HAUGK and COLSMANN, who have illustrated by their writings the doctrine of galvanism. That the Germans have laboured with their wonted assiduity in this investigation, is evinced by the numerous works they have published on the subject. Several of the writers of this nation have been already mentioned, and more particularly CREVE, who has written very extensively against GALVANI and his partizans. At a very early date after the galvanic phenomena had been noticed, he communicated his observations on human limbs subjected to amputation; and recommended the employ-

ment of galvanism in the discovery of real death, pointing out the mode by which it ought to be distinguished from apparent death brought on by asphyxia, or any other cause. The advice he gave on this head appeared in a dissertation published by his pupil KLEIN, on the subject of the efficacy of metallic irritation in the discovery of real death. This dissertation appeared in 1794.

About the same time, that is, in 1793 and 1794, PFAFF published several papers on galvanism, in the Latin and German languages, in which he combined his own experiments with those of the other physiologists. He made a variety of researches on the species of electricity which he stiles animal, and added the details of the purposes to which it may be applied in natural philosophy and medicine.

He was very soon followed by HUMBOLDT, whose writings infinitely surpass those of his predecessors, as well on account of the abundance of scientific knowledge they contain, as of the ingenuity displayed in them. The works of this learned naturalist, as they are cited by REINHOLD, consist of three letters addressed to the celebrated BLUMENBACH, and another to CRELL, published in the German Scientific Journals. A letter addressed to M. PICTET, inserted in the *Magazin Encyclopedique*, on the influence of the oxygenated muriatic acid, and on the irritability of the organic fibre.

Another

Another letter to M. DE MONS. And, lastly, his principal work on galvanism, published in 1797, a particular account of which will be given in the sequel.

REINHOLD concludes the list of the authors who have professedly treated the subject of galvanism, by a short notice of those who have spoken of it in a cursory way, in the diurnal prints, or other periodical publications. It will be simply necessary to cite in this place the theoretic dissertation on the principle which gives birth to epidemic fevers of an inflammatory nature, by ESCHENMEYER. This author makes the atmospheric miasma by which these fevers are produced, to reside in electricity; and undertakes to prove, by galvanic experiments, that his opinion is well founded.

REINHOLD next points out the order he means to observe, in treating the subject matter of his two dissertations. He confines himself to experiments purely galvanic, as they relate either to the different parts of the animal organization, or to the bodies which are conductors of the galvanic fluid, applied to the animal, and in mutual contact with each other. In the detail of these experiments, he relates those which demonstrate the effects of the galvanic fluid, in the first instance on the irritable fibre, and afterwards on the sensible fibre. In other words, he details the experiments relative to movement and sensation.

He has classed these experiments under their respective heads, from a conviction that movement and sensation, although arising from the same source, as he endeavours to demonstrate in the sequel, differ notwithstanding, according to the mode in which the animal is prepared for the experiment, and according to the disposition of the galvanic apparatus. On this latter head, he observes that the coatings* may be applied, either

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* The *coating* is a substance which, being applied to a part of an animal capable of being incited, gives motion to the galvanic fluid, by embracing it in some way or other. It is then said that the part is *coated*, or *armed*. It is of little moment whether the coating be above, below, or at the side of the part to be acted on, provided it touches it precisely at any one determinate point. Two kinds of coatings are employed, relatively to the parts they touch, namely, that of the nerves, and that of the muscles. Several authors have bestowed on the latter the name of *exciting arc*, but improperly, since it has been proved by more recent observations, that the two coatings, that of the nerve, and that of the muscles, possess alike the excitative faculty. It is true, that several of them, when applied to the nerves, or to the muscles, produce more extraordinary effects than the others, and excite a greater number of galvanic phenomena, as well as more powerful ones. REINHOLD divides the coatings into *nervous* and muscular; or, if it should be wished to disregard their faculties, and merely to consider the nature of the part armed, the one applied to the muscle may be entitled *coating of the muscle*, and the one applied to the nerve, *coating of the nerve*. In this case C. M. may be employed, by abbreviation, to distinguish the former; and C. N. the latter.

on

on the nerves and muscles at the same time, on either of them separately, or on other humid substances contiguous to the animal, taking care, however, that they do not touch it at any given point. The movement and the sensation likewise differ, according to the media which surround the animal with the apparatus; according to its *incitability*, more or less modified by the agents; and, lastly, according to the different nature, the different distribution, and the different assemblage of the substances with which the animal is armed, or by which the coatings are united. In proposing to cite the authors of each description of experiments, together with the variations they have experienced, REINHOLD deems it necessary, in the first place, to say something of the animals themselves, and of the mode of preparing them for the experiments.

It is well known that, since the commencement of the discovery of galvanism, the experiments have been most frequently made on frogs, and more especially on the species denominated by LINNÆUS *rana esculenta*. This has unquestionably been done on account of the facility with which frogs are found, as well as on account of the vital force which subsists in them a considerable time after death, and of the particular structure of their body and nerves. It is certain at the same time, that their preparation is much

easier than that of other animals. It is of little moment, whether an animal destined for experiment be in health and in an entire state, or, on the other hand, prepared and dissected.

With respect to the preparation, four differences have been established by physiologists. Some of them merely deprive the animals of their integuments to the muscles. Others, after having opened the cavities of the thorax and abdomen, and removed the viscera, denudate the nerves and muscles distributed in those parts. Others, again, after the animal has been prepared in this manner, separate all the parts between the origin of the nerve and its insertion in the muscle, insomuch that the latter is attached to the rest of the trunk by the nerves only. Several naturalists, after having prepared the animal as above, cut off its head, to the end that the movements excited by galvanism, may not be deranged by the voluntary movements, and a confusion ensue between them. The fourth kind of preparation consists in the entire separation, by dissection, of each of the parts from the rest of the body; the extremities, for instance, or any one of the muscles, after it has, as well as the nerves, been laid bare. Those who are desirous of further information relative to the best modes of preparing animals destined for galvanic experiments, may consult SCHMUCK, GREN, and CAVALLO, the

latter

latter of whom has illustrated this subject by a plate.

In the second section of his dissertations, REINHOLD treats of the contractions of the muscles, produced by animal substances brought into contact. These contractions are excited in animals replete with vigour, more particularly frogs, so long as the incitability * is in a highly exalted state. When they have been prepared in any one of the modes explained above, one of their solid parts, in a humid state, should be brought in contact with another incitable part destined for motion, in such a way as that the former may constitute an arc touching the nerve or the muscle, or both of them at two points. It is of little moment, whether the part which is brought in contact be organically united with the part it touches, or taken from any other animal.

HUMBOLDT, ALDINI, and VALLI, were struck by this discovery, the merit of which is entirely due to GALVANI. They repeated the experiment on a frog, the inferior extremities of which were connected with the body by the ischiatic nerves only. No sooner was the communication established, than violent contractions and movements were perceived in the leg; insomuch, that the gemelli muscle and internal gastrocnemius

* We have adopted, with REINHOLD, the words *incitability*, and *incitable*, because he employs them in preference to those of *irritability* and *irritable*.

were

were drawn up towards the muscles of the thorax, and towards the ischiatic nerve, to such a degree as to touch these parts. The same phenomenon was observed, when the above nerves, or a part of the medullary substance, came in contact with one of the lower extremities. It was then perceived, that the movements were augmented in a greater or less degree, in proportion as the parts to be brought in contact were moistened with saliva, with a solution of saline substances, or with soap and water. The effect does not cease when the nerve and the muscle are united to a humid part of an animal with which they have not any organic union. These phenomena will be more particularly explained in the sequel.

Our author next proceeds to describe the contractions excited by non-animal heterogeneous substances, either in animals in an entire state, or prepared according to the methods described above. These heterogeneous substances consist of the coatings, which he divides into muscular and nervous, and with which VOLTA, VALLI, CORRADORI, FOWLER, MONRO, PFAFF, and ACKERMANN, have made a variety of curious experiments. He speaks also of the movements produced on living persons by these coatings; and of those resulting from the application of zinc and silver within the cheeks. He notices particularly the experiment of HUMBOLDT, who produced, by the means of metallic substances, contractions in the muscles, after

having

having removed the epidermis by a blistering plaster; and that of ACHARD, who noticed distinctly the augmentation of the peristaltic motion, when he introduced, after having applied to the tongue a bit of zinc, a piece of silver into the anus. In this case, the sphincter muscle having been made to contract, the desire to go to stool soon followed, and was succeeded by the evacuation itself. GRAPENKIESSER notices, that he has seen the above motion accelerated, by the same means, in the case of a man whose large intestines, formerly contained in a hernial sac, had, in consequence of an abscess in the part, formed an artificial anus. This observation will be particularly dwelt on hereafter.

Relatively to the contractions excited in dissected animals, by coating the muscles and the nerves, REINHOLD observes that, after the integuments have been removed, and the muscles and nerves duly prepared, when the latter are not yet destitute of their vital energy, that is, when they are still humid, and susceptible of contractions, if, under these circumstances, the coatings are well conditioned, and applied in a proper manner to the incitable animal, there ensues a kind of *tetanos* in every part of the body. But if, on the other hand, weak coatings be employed, or if the incitability of the animal be nearly extinguished, no other than very feeble commo-

commotions will be obtained. It has thus been noticed that the brain, or medullary substance, being armed, all the muscles provided with nerves which lead from those parts do not contact, but merely those which proceed from the part which is coated, or from its vicinity. It has in general been ascertained by facts, that the movements are very powerful, whenever the nerves are surrounded by the galvanic fluid in an insulated state, whether this be throughout their whole extent in the muscles, or, at the least, at a small distance from the point where they are distributed. The humid coatings produce the same effect as those which are dry, operating as powerfully as the metallic coatings themselves. On this head, REINHOLD observes that, by the means of the liver of sulphur and the muriatic acid, united by silver, he had several times succeeded in exciting as powerful contractions as with gold and zinc. CREVE goes so far as to assert that the galvanized extremities of frogs, on which he laid iron and the copper of Japan *(cuprum Japonense)* became so violently contracted as to raise, in the first instance, a pound weight, and afterwards upwards of two pounds.

The contractions take place, not only when heterogeneous coatings are employed, but likewise, more feebly, it is true, when the application of homogeneous coatings is made. This fact has

has been questioned by several naturalists, among whom may be cited GREN, MICHAELIS, and VOLTA. The latter has even asserted, that those who had observed contractions to result from homogeneous coatings, had been led into an error, when they ascribed to similar metals the same nature, without paying a sufficient attention that this nature frequently varies at each point, in consequence of the degree of roughness or polish of the metals, of their thickness or tenuity, of their unequal surface, of the mode in which they are applied to the parts, and, lastly, of several other unforeseen circumstances, which very frequently change the power of the coatings, thus influencing the result of the experiment. Those made by ALDINI and HUMBOLDT, and which were often repeated, set aside all the reasonings, as well as all the facts, founded on the opinion of VOLTA. HUMBOLDT obtained contractions by bringing mercury, well purified, and in a homogeneous state, in contact with the muscle of a frog carefully prepared. REINHOLD frequently succeeded in exciting movements, by placing beneath the crural nerve, laid on a bit of glass, the torn edge of a flattened piece of zinc, in such a way as that it touched the nerve at one point only. Several other experiments have proved that homogeneous moist coatings are also capable of exciting movements.

In

In giving an account of the experiments made by the means of the ligature of the nerves, and of the effects which, according to HUMBOLDT and VALLI, result from them, REINHOLD takes occasion to notice another fact observed by GALVANI, MONRO, FOWLER, and CALDANI, a precise explanation of which was first given by PFAFF. The latter having perceived that the movements were unusually feeble, when the crural nerves were laid in a moist basin, ascribed to humidity the dissipation of the operating fluid, and the cause of the diminution of its effects. It is on this account that he endeavoured to ascertain, whether other substances, conductors of the galvanic fluid, would produce the same effect, if brought from the coating of the nerve, and directed towards the denudated muscles. The result was, that he found the movements to be, in almost every case, weakened by similar derivations of the galvanic fluid; insomuch, that they were sometimes in a languid state, and at others ceased altogether, according to the variety of these derivations. The same author, as well as VOLTA and FOWLER, noticed the movements which take place at the moment the coatings are separated from each other.

Nothing certain has been acquired relatively to the interval of time during which the galvanic contractions can be excited, their duration depending

pending on the nature of the animal, as well as on that of the experiment. This has given rise to a great diversity of opinions. With the exception, however, of CALDANI, all the physiologists agree in opinion, that the contractions excited by galvanism are of longer duration than those which are procured by mechanical agents. They consequently maintain that the loss of incitability cannot be ascertained, until fruitless efforts have been made to awaken this dormant faculty. REINHOLD having placed a piece of tin beneath the nerves, and a piece of silver beneath the muscles of several aged female frogs, found that the muscles scarcely contracted at the expiration of sixteen hours. FOWLER observed convulsive movements of the muscles of animals of this description, sixty-two hours after their death; and CREVE, as well as HERMESTAEDT, found these movements to be of a still longer duration. The latter remarked them in a tortoise during three days, the water in which the animal was kept having already become in a great measure putrid.

The sagacity of physiologists, by which they were enabled to notice these movements in the muscles governed by the will, led them to the discovery that they are likewise produced, by the means of the galvanic fluid, in the parts which are not obedient to the will. They set out by experi-

experiments made on the heart. All those who, a short time after GALVANI's discovery, employed themselves in experimenting on that viscus, denied that it could be acted on by the galvanic fluid. This was the joint opinion of SCHMUCK, MEZZINI, VOLTA, VALLI, KLEIN, PFAFF, and BEHRENDS, the latter of whom concluded from this circumstance, that the heart is unprovided with nerves, which merely accompany the vessels. REINHOLD gives a detailed account of the experiments made on this subject by the above physiologists, as well as by others, such as FONTANA, GIULIO, FOWLER, HUMBOLDT, CREVE, LUDWIG, WEBSTER, and MICHAELIS. He directs his attention particularly to those of HUMBOLDT, who, to ascertain with precision whether the galvanic fluid possesses the faculty of giving motion to the heart, and whether this faculty acts by the medium of the nerves only, made several very ingenious experiments, in concert with his brother. He found, that on carefully preparing and coating the very small nerve which proceeds to the heart, instantly after the animal had been killed, the heart itself moved in every part, insomuch that its contractions, when they had ceased, were either excited afresh, or accelerated when they were feeble. To remove every suspicion of mechanical *stimuli* capable of irritating the substance of the heart, M. HUMBOLDT laid over it bits of muscle,

muscle, to which alone he applied the coatings. The same effect took place, without any difficulty.

These experiments were repeated by Reinhold on frogs, rats, hares, and cats, with a nearly similar result. He remarked, however, that the humid coatings, more especially those which experience has proved to be the best, connected each with a metallic substance, excite in the heart movements equally powerful with those produced by metals only. This happens, whether they be applied to the nerves and muscular fibres separately, or to both at the same time. It should, however, be noticed, that the movements which are excited, when the nerves and the fibres of the heart are coated at the same time, are invariably more powerful than the other movements, &c.

In experiments made on the stomach and intestinal canal of a cat, there did not result any movement from a coating with zinc and silver, applied on the stomachic flexus, and on the semi-lunar ganglion. Monro has, notwithstanding, seen the extremities of a frog thrown into convulsions, by the union of zinc, applied to the back, with gold introduced into the *intestinum rectum.* The same observation was made by Humboldt. Having bound the inferior extremities of a frog, laid on a sheet of zinc, the animal leaped to a considerable distance, with an incredible force, as soon as he had introduced into the

anus a silver wire, and brought it near the other metallic substance. He also perceived, in birds which lay without any signs of life, the fluttering of the wings, after he had brought in contact the zinc with which the tongue was coated, and the silver introduced into the straight gut. By this method, he, as well as VALLI, contrived to restore these animals to life.

Similar experiments, made on the urinary bladder, matrix, diaphragm, arteries, and veins, were more or less successful, or failed altogether, according to the mode in which they were executed. Those of FOWLER, which, according to the reasoning he established on them, demonstrated that the movement of the blood, in the arterial system, is accelerated by galvanism, proved to REINHOLD quite the reverse. The influence of the galvanic fluid on the arteries has been, nevertheless, fully demonstrated, seeing that HUMBOLDT experienced it on himself. Having applied to the parts of his body which he had purposely blistered, zinc and silver, he constantly observed, that the seroso-lymphatic humour which exudes from the vessels deprived of the epidermis, being excited by the galvanic fluid, flowed out in a greater or less degree. He noticed also, that it changed its nature and colour, corroding the parts of the back he had chosen for his experiment.

It

It was repeated by REINHOLD on three sick persons. In the case of the first, the phenomena noticed by HUMBOLDT were manifested; but the second did not appear to have been acted on by the galvanic fluid. It should be observed, however, that he had been attacked by a rheumatic ophthalmia, and was therefore galvanized once only. The third patient had a venereal ulcer, which was nearly cured. The following observations were made on this latter occasion. On the first day nothing remarkable occurred, except a painful itching. On the third day, the purulent discharge of the ulcer having been removed, a humour of a pale red colour was observed to ooze out, producing on the edges of the ulcer a considerable degree of inflammation, which, however, soon subsided. According to REINHOLD, this arose from the following causes: First, because the patient was of a phlegmatic temperament. Secondly, because the incitability of an old ulcer is not so great as that of a part the epidermis of which has been removed a short time before the experiment. And, lastly, because a part to which cantharides have been applied, is more favourable to galvanic experiments than an ulcer, seeing that it has a greater extent of surface, and will consequently admit of the application of a larger muscular coating. A phenomenon which likewise proves the ascendancy

of the galvanic fluid on the arteries, consists in the discharges of blood from the parts which have been galvanized, from the nostrils, according to the authority of MONRO, and from the ear, according to FOWLER.

REINHOLD next treats of the contractions of the muscles, excited by coatings which embrace the nerves only. He observes, that in this case the coatings excite movements in the muscle, the nerve of which they embrace, as effectually as if they had been applied both to the nerve and to the muscle. This fact has been denied by the partizans of the theory of GALVANI, although the latter asserted that it had been noticed by him, and although it has been proved by other physiologists, such as VOLTA, VALLI, MONRO, FOWLER, and CREVE. The latter adduces several examples, to demonstrate that the contractions which result from the simple coating of the nerves, are of a considerable duration. If they disappear sooner than when the nerve and the muscle are both of them coated, it is because the nerve, being more frequently touched, and in a greater number of its parts, does not retain its activity so long as in the other case. On this subject CREVE inquires, whether the movements excited by the nerves, when enveloped in a coating, are more powerful, and of a longer duration, than those excited by the uncoated nerves. He declares himself of opinion that they are; and brings

brings forward an experiment in support of his reasoning.

REINHOLD, who does not entirely agree with him, ascribes the weaker movements, in the latter instance, to the contact of the nerves and muscles, the contractions of which have been excited with the adjacent parts, and to the derivation of the galvanic fluid, which is the necessary result. As an evidence of this he observes, that any one of the muscles destined to move the eye, produces as powerful movements as any other of the voluntary muscles, if the nerve which governs its motion be properly coated, after having been dissected and insulated near its origin in the brain. He is, besides, of opinion, that the membrane with which nearly the whole of the nerves are provided, except at a small distance from their origin in the brain, acts as a conductor of the galvanic fluid to the nerve.

Relatively to the movements which are produced when the muscles alone are coated, GALVANI, VALLI, VOLTA, and VASCO, were the first to start the doctrine, which all those who have written after them have embraced, that the movements equally take place when the coatings of this description are united, as well those which embrace different muscles of the same animal, as those which are applied to one and the same muscle. REINHOLD observes that, by the means

of humid coatings, he could with difficulty excite very feeble movements only; and that, with homogeneous coatings, he could not obtain any, except in the case of very irritable frogs, and that only in the parts where the nerves were covered with a very thin layer of muscular fibres. He notices the experiments made by HUMBOLDT, of which we shall speak more particularly hereafter, to ascertain whether the galvanic phenomena are owing to the nerves or to the muscles. He himself observed movements, of from eight to fourteen hours duration, excited in the muscles of a frog which had been kept in the shade, in a temperate and somewhat moist atmosphere. He likewise remarked that these movements, although more feeble, were of a longer duration than those excited by the coatings applied to the nerve only; which will not appear extraordinary, when it is considered that the muscle, having a much larger superficies than the nerve, in consequence of which it must be much longer in drying, presents to the contact of the coatings a much greater proportion of humid and irritable parts than the latter.

On the subject of the movements excited by coatings added to humid substances, conductors of the galvanic fluid, and contiguous to the animal itself, he observes that VOLTA is the earliest physiologist who spoke of this method

of

of exciting movements. He was followed by MONRO, FOWLER, CAVALLO, and PFAFF, the latter of whom made a variety of very curious experiments on this subject, which he discussed with great ability. REINHOLD is of opinion, that to this class of experiments ought to be added those which consist in joining to the nerve, or to the muscle, one of the coatings which touches the other in an immediate way, either by the means of some moist part of the human body, such as the hand, or by fluid conductors. He denies, however, that the experiments in which the coatings, in embracing the animal itself, are united by such a substance, contiguous to each of them, are to be considered as belonging to the same class. He thinks, on the other hand, that experiments of this nature ought to be comprehended among those in which the coatings are united by bonds of a diverse nature.

The coatings are applied in three different states, according to the nature and description of the humidity which is employed to conduct the galvanic fluid. Thus an application of the coatings is made either to the humid parts of animals and plants, or to non-organic substances moistened in any given manner; or, lastly, to fluids themselves. With respect to the movements excited by coatings applied to parts belonging to the animal organization, they are

equally perceptible, whether raw flesh be employed, or flesh that has been previously dressed. HUMBOLDT has proved that the parts of plants, covered by their epidermis, can scarcely be considered as conductors of the galvanic fluid, and that they cease to be so altogether, after the epidermis has been removed. On this head, FOWLER and PFAFF were guilty of an error, when they asserted that plants in general have a conducting faculty. They have, however, made several excellent observations relative to the movements excited by coatings applied to humid, non-animal substances. In investigating this subject, REINHOLD found that the effects are the same in coating either paper, leather, linen, soap, or any other substance moistened by any particular fluid acting as a conductor, with the exception of those which change the incitability, such as the acids and alkalis. The movements cease, however, as soon as an application is made, either of oil, of the solutions of gums and resins, of wax, mercurial ointment, or ice.

The following is a curious experiment made by REINHOLD, on the vital force, and on the effect of the circumambient air. While he was holding in his hand the legs of a prepared frog, he perceived the part of the spinal marrow which supplies the crural nerves, to be, instantaneously

as

as it were, in a tremulous and convulsed state, notwithstanding the scissars he held in his other hand were about a line distant from the part in question. Suspecting that, either by the oscillation of the nerves, or by the involuntary trembling of the hand, the scissars might, perhaps, have touched the medullary substance, he made the experiment in another manner. He laid on glass the extremities he held between the finger and thumb, in such a way as that the nerves and medullary substance should be freely suspended in the air. His other hand, in which he held the scissars, rested on a board which was not contiguous to the spot where the animal was placed. On his bringing the scissars near the medullary substance, movements, similar to those in the former instance, were observable; and the effect was invariably the same when the experiment was repeated on other frogs. But, however near he brought the scissars to the coating of the muscles, he could never perceive any movement to take place. Zinc was of equal utility with iron in producing the contractions referred to above; but he was not successful in his trials, either with other metals, or with humid coatings.

Reinhold afterwards made several of that description of experiments in which the coatings, brought into immediate contact, are applied to fluid conductors of the galvanic influence, communicating,

municating, in a direct way, with the animal. For this purpose he tried the galvanic forces of several fluids, such as spring-water, rain-water, distilled-water, milk, arterial and venous blood, soap, urine, the juice of plants, spirit of wine, solutions of neutral salts, alkaline liquors, acids, and oil. In every instance, except in the case of the oil, more or less powerful contractions were displayed by the animals. Authors differ widely in their opinion relative to the conducting property of spirit of wine, probably on account of the manner in which it is prepared, and of the want of a due attention, on their part, to the power it has of changing the incitability.

Our author here notices the galvanic experiments made on all classes of animals, as well as on vegetable substances. They prove that there is scarcely any animal, whether quadruped, bird, fish, insect, or worm, that is not more or less susceptible of galvanic irritation. It is the same with plants. The very ingenious experiments made by M. HUMBOLDT, already detailed in this work, prove that they are alike influenced by this principle. REINHOLD endeavours to explain the reasons why the changes produced in plants by galvanism can very rarely be perceived. They are as follows;

1st, Because several plants require a specific stimulus to excite them.

2dly, Be-

2dly, Because, in their case, the excitement takes place so speedily, by the humours which circulate in the vessels, and by the augmented secretions, that the human eye cannot perceive them.

3dly, Because the irritable fibre is too deeply seated beneath the bark and the other parts, which find a difficulty in conducting the galvanic fluid. If, with a wish to coat the fibre itself, these parts be divided and withdrawn, the hemorrhage which is the result of the incisions, either entirely destroys, or considerably weakens, at the least, the incitability of the plant.

4thly, and lastly, Because all the movements excited by plants, with the exception of those observed in some particular ones, appear to belong to the class of involuntary motions, which it is extremely difficult to excite in animals, by the means of galvanism.

The third section of REINHOLD's dissertations is devoted exclusively to experiments relative to the external senses. In the same way as the motive faculty of the nerves, excited by a *stimulus*, produces movements, so likewise does the sensitive faculty produce sensations. Both the movements and the sensations are excited by galvanism, in a greater or less degree, according to the nature of the nerve. Our author begins by detailing the experiments relative to the sense of taste.

taste. VOLTA first noticed that a coating of the nerve, applied to the point, or to the inferior surface of the tongue, and a coating of the muscle applied to the superior, excite, the instant they are brought in contact, an acidulous taste, similar to the one which is perceived after the tongue has been burned. If the places of the coatings be changed, in such a way as that the one belonging to the upper part of the tongue may occupy the lower part, and *vice versá*, the above taste will become acrid and alkaline. This experiment having been several times repeated, in different ways, by various naturalists, produced as great a variety of effects, which are specified by REINHOLD, and which, according to him, depended in a great measure on the greater or less degree of sensibility of the tongue. With respect to the kind of taste which is perceptible, HUMBOLDT doubts whether it is entirely to be ascribed to galvanism, and finds so great a difficulty on this subject, that he does not undertake to resolve the question. It should be noticed that, in this case, the effect of the galvanic fluid consists entirely in the excitement of the nervous *papillæ* of the tongue; which excitement obliges the vessels to supply a humour similar to the one they furnish in the ulcers produced by vesicatories.

The galvanic fluid has, at the least, as powerful an action on the organ of sight, as on that of

taste.

taste. The experiments on this head are more curious than the others, and indeed more decisive as to the effects of galvanism. Reinhold cites a considerable number of them, made by different naturalists, as well as those made by himself. The following are the most important ones: The visual nerve having been carefully coated, or armed, as soon as the coatings are brought together, a sudden burst of light is perceived, which, like a flash of lightning, strikes the eye, whether open or closed, and which is as apparent in the dark as at mid-day. It ought, however, to be remarked, that the glare of light is more brilliant when the eye is shut in an obscure place, than when it is open in a place exposed to the sun or light. It is likewise more brilliant when the nervous coating is applied over the eye itself, the silver being, consequently, over the right eye, and the zinc over the left. The latter, in this case, is sensible of a greater splendour of light, as Reinhold has sometimes observed, at the instant the metals are withdrawn from each other.

What is still more surprizing is, that this light is manifested, not only on the application of the coatings to the eye itself, but also on a similar application to other parts. Four different modes, for its production, are described by Humboldt. The most remarkable is the one by which it was made very apparent, when, after having laid on the

the tongue a bit of zinc, the above physiologist introduced into the straight gut, to a considerable depth, a piece of silver. FOWLER observes, that he has seen, in the case of himself and several other persons, in addition to the glare of light, which was very evident, a contraction of the pupil. This appeared to him to demonstrate the influence of the galvanie fluid on the iris. These contractions of the pupil were not, however, observed either by HUMBOLDT or PFAFF. REINHOLD having forced the zinc high up into the nostril, at the same time that the tongue was covered by a piece of silver, and the two metals having been brought in contact in an obscure place, repeatedly observed the contraction of the pupil, which takes place more particularly in an eye, the incitability of which has been augmented by inflammation. The tears, without any change being operated in their natural quality, flowed more copiously, at the instant when the zinc, applied to the internal angle of the eye, and the silver, laid on the upper lip, were brought in contact. The experiments of PFAFF, CORRADORI, and MONRO, have demonstrated that the galvanic burst of light, and the taste, are likewise excited, when the coatings are applied, not to the organ itself, but to other humid substances.

The galvanic fluid appears also to have an influence on the organ of smell, as appears to be

be proved by the following experiment made by CAVALLO. He observes that, having brought together a silver thread, forced as high up as possible into the nostril, and a piece of zinc, laid on the tongue, he was sensible of a putrid smell, more especially after having forcibly pulled the silver in the nostril. REINHOLD repeated this experiment several times, but without any such result.

According to the latter, if any reliance can be placed on the experiments hitherto made on the organ of hearing, it seems to be proved that it is in no way susceptible of the impression of the galvanic fluid. FOWLER is of opinion that, in these experiments, the blood which is discharged during the night, from a galvanized ear, arises rather from a mechanical injury than from any other cause. REINHOLD, on the other hand, thinks that this discharge ought to be ascribed to the action of the galvanic fluid on the vessels.

He agrees with FOWLER and PFAFF, that the organ of feeling is not more susceptible to the impressions of the above fluid, than that of hearing. The same symptoms of pain which VALLI, FOWLER, and PFAFF observed to manifest themselves occasionally in animals, by the contact of metals, REINHOLD has almost invariably distinguished in animals endued with great sensibility. Among these demonstrations he comprehends the

the disgust testified by a dog whose tongue had been coated. It is proved by other experiments, that the galvanic fluid affects each of the nerves, more especially when laid bare, and in a highly sensible state. Thus, when ROBISON united to the silver with which the tongue was coated, the zinc applied to a wound, he felt a pain in the part where it was seated. He also found that a carious tooth became painful, with a disagreeable itching sensation, when the zinc with which it was coated, was brought in contact with the silver applied to the muscles of the mouth. HUMBOLDT augmented the inflammation of a wound of the skin, by galvanizing it, and brought on a blunt, throbbing sensation of pain, accompanied by an itching.

The fourth section of REINHOLD's Dissertations contains practical experiments made in the different *media*, which are, according to him, endowed with four different kinds of functions.

1st, Being contiguous to the animal on which they act as a coating, they excite the galvanic fluid.

2dly, Being formed into an arc, in any given part, they either retard, or favour the progress of that fluid.

3dly, Not being disposed in the form of an arc, they change the effects, on this account, that, while the galvanic fluid is dissipated by other

other bodies, conductors of the galvanic fluid, certain other bodies, again, in an insulated state, press that fluid more powerfully both on the animal and on the arc.

4thly, and lastly, they affect and change the nature of the animal, and of the coatings, in such a way as to derange both the experiments and their results.

Among these *media*, the atmospherical air is not the least important. It influences, on the other hand, in a conspicuous degree, all the phenomena of galvanism. When it is charged with a considerable portion of electricity, more particularly on the approach of a storm, it is extremely favourable to galvanic experiments, which not only succeed much better under these circumstances, but are also accompanied by effects not to be observed under any other state of the atmosphere. The experiments made by Galvani, Humboldt, Michaelis, and Reinhold, are striking evidences of this fact. In attenuated, as well as in condensed air, the effects are, according to Aldini, equally singular; insomuch that he found the movements to be weakened in the former of these airs, and augmented in the latter. Creve, however, by whom his experiments were repeated, could not perceive any alteration in the effects, in either of the above airs. It results from the observations of Hum-

BOLDT, that the galvanic experiments succeed as well in the oxygen, nitrous, hydrogen, azote, and carbonic gases, as in the atmospherical air; but that the oxygenated muriatic gas excites the most powerful movements, and the gas named by the French chemists *hydrogène-pesant* (carbonated hydrogen gas) the weakest.

The fifth section treats of the conditions necessary to produce, in animals, the galvanic phenomena. These conditions are divided by REINHOLD into two classes, namely, into those depending on the animal, and those dependent on the arc and the coatings. In the number of the authors who have written on this subject, there are three only, SCHMUCK, PFAFF, and HUMBOLDT, who have entered into a precise explanation of these conditions.

The principal one required in an animal, is the existence of a sensible fibre in the part on which the galvanism is to act. This fibre ought also to be irritable, to excite the movements. The existence of nerves capable of producing both the sensibility and the movement is consequently essential, it having been demonstrated both by VOLTA and MUNRO, that galvanism acts on the nerves alone. PFAFF is of opinion, that the powerful movements, which are at the same time of a considerable duration, can only take place in a muscle amply supplied with nerves. This may be

be true, observes REINHOLD, so far as it relates to the muscles which have a simple function to perform, or which belong to the same organ; but the proposition is false, if it be extended to all the muscles. The experiments made by HUMBOLDT have placed it beyond any doubt, that the greatest effect is invariably produced, when the action of the galvanic fluid is determined to several very large nerves. With respect to the irritable fibre, which appears to be as necessary as the sensible fibre, in the excitement of galvanic movements in the muscles, it is not to be constantly found in each part of the animal organization; notwithstanding which, in parts where it cannot be met with, in the iris, for instance, the movements take place. HEBENSTREIT, in speaking of other irritable parts of the human body, has evidently proved that several of them, although entirely divested of muscular fibres, swell by the means of the vital force which is excited in them. To conclude on this head, the experiments made by MUNRO, HUMBOLDT, and REINHOLD, clearly demonstrate that the organic union of the nerve with the muscle, is in such a degree essential to the contractions, that if the muscle be divided at the part where the nerve is inserted, all movement will cease, whatever attempts may be made to bring together the divided portions.

The vital force is also, in an animal, one of the conditions without which no success can be obtained in galvanic experiments. But as its degrees and modifications are innumerable, so must the diversity of the galvanic phenomena which result from its excitement, be likewise very great. Reinhold enters into a variety of details relative to the nature, cause, and descriptions of these modifications. After having defined the *incitability* of a living and organized animal part, that is, *the faculty by which this part, being itself impelled to incitability, re-acts according to the laws of its organization, and of its nature*, more especially in the operation of galvanism, he observes that it may be changed in two ways, by exaltation or by depression, by which two descriptions of it are established, the one natural, and the other artificial.

The next consideration into which Reinhold enters, is the incitability exalted by a natural mode, whether physiologically or pathologically. The incitability, when physiologically exalted, may have several causes, and several differences, derived from the nature and organization of the animals, according to the different classes to which they belong. Of these classes there are several which have been considered as less incitable than the others, because we are not as yet fully acquainted with the means of preparing them for the

the experiments, which, on that account, do not succeed so well. The sex of the animals also occasions a difference, the female frogs being, according to HUMBOLDT, more incitable than the males. REINHOLD has noticed the same singularity, as well in these animals, as in birds and fishes. It may be added, that an equal degree of incitability does not exist in every part of the same animal. VOLTA asserts, that the effects of galvanism are less apparent in animals of large dimensions, on this account; that there is a more extensive distribution, in their case, of the galvanic fluid. He affirms, that the only animals which are susceptible of galvanism, are those that have their extremities articulated by flexor muscles, and distinct nerves. PFAFF, whose only mode of estimating the degree of incitability, is by the time during which it is perceived, is of a contrary opinion, and insists that large animals are more incitable than those of the smaller tribes.

REINHOLD demonstrates, by several examples, that this faculty does not subsist at all times, and at all ages. Young animals are more incitable than old ones; insomuch that the experiments made on the former, when recently killed, are often successful, while those made on the latter fail altogether. It is true, that the galvanic phenomena which do not require a great degree of in-

 citability,

citability, are of a longer duration in aged animals. The class of *amphibii*, after their winter sleep, are very incitable. Frogs are less so than usual during the months of June, July, and August, when the incitability is feeble and blunted. A tranquil existence also diminishes the incitability, which an active life, on the other hand, augments. That it is also influenced by climate, has been demonstrated by HUMBOLDT, who observes that Italy is more favourable to galvanic experiments than Germany.

To form a precise opinion of the incitability of animals after death, regard must be had to the time which has elapsed after the animal has been killed, seeing that, on this head, great differences depend on the longer or shorter duration of this space of time. Instantly after their death, REINHOLD tried a variety of experiments on young and aged animals, killed at the same time, and in the same manner, and repeatedly noticed that, in the case of the former, the movements were more impetuous, but of a shorter duration; while, in that of the latter, however feeble they might be, they continued for a greater length of time. He consequently infers that the young animals were more incitable immediately after their death; but that the aged ones continued longer in a state of incitability.

FOWLER was the first to remark that the inflamma-

flammation of any given part exalts its inherent incitability. REINHOLD observed the same phenomenon in the instance of the thigh of a frog, which became inflamed two days after it had been wounded with a knife. The contractions, however, soon ceased. He made several experiments on ophthalmias and venereal ulcers, with a view to ascertain the influence of diseases in the modification of this faculty. As he could not come to any direct conclusion on this head, he forbears to enter into any detail relative to the result of his observations.

He also made, as well as VALLI, VOLTA, FOWLER, CALDANI, CREVE, SCHMUCK, CAVALLO, and PFAFF, a considerable number of experiments on the species of incitability that may result from the kind of death to which an animal is subjected. These experiments convinced him that the incitability is invariably the same, whether the animals be strangled, or drowned in any fluid whatever, spirit of wine excepted; or the head either cut off or crushed; or the body cut and divided in various directions; or, lastly, if, as VOLTA has done, they be killed by plunging a needle into the medullary substance. It is true, that the incitability which is, in these instances, manifested, differs according to the quantity of blood that has been spilled, and to the more or less sudden nature of the death; the animals which have lost

the smallest portion of blood, or which have been killed suddenly, being more incitable than the others. Those that have perished in a muriatic oxygenated air, seem to be the most incitable. Among those that had been poisoned, REINHOLD did not find a single one, which, after its death, was more incitable than when living.

He next proceeds to consider the incitability exalted by an artificial mode. The observations made by physiologists on this description of incitability, vary considerably, and are for the greater part contradictory, more especially as to the employment of opium, which is said by some, when applied externally to an animal, to render it more incitable, while others contend, that it does not modify the incitability in any degree; and others, again, that it tends to depress it. This discordance of opinions having urged REINHOLD to try the effects of opium applied to the nerves, he found that by bathing a nerve with a mixture of an ounce of depurated opium dissolved in three ounces of water, he constantly augmented and exalted, during a certain lapse of time, its incitability; and that an equal quantity of the solution, applied to the muscles, had not the smallest effect whatever in modifying the irritability. HUMBOLDT made precisely the same observation. Having prepared the phrenic nerve of a dog, immediately after the animal's death, in

in such a way as that it hung freely in the air, in a denudated state, to the length of five inches; and having plunged its extremity in a fluid well saturated with opium, the spectators perceived not only a general tremulous motion of the part, but likewise, as soon as it was metallically coated, movements of the diaphragm still more powerful than those which the coatings had produced before the opium was employed.

By the latter physiologist we have been taught, that the oxygenated muriatic acid, the arsenical calxes, and alkalis, more particularly the deliquescent oil of tartar, when applied to the nerves, have the effect of exalting their sensibility in an extraordinary degree; insomuch that a few drops of oil of tartar, poured on a crural nerve suspended in the air, in such a way as that every part of the nerve, to its insertion in the muscles was moistened, excited in the limb tetanic convulsions.

Authors are much at variance relatively to the question, whether the movements can be re-excited by moistening the nerve with water. In his experiments on frogs, REINHOLD frequently succeeded in resuscitating the languid movements, by the means of a few drops of distilled water poured on the nerve, while it was still in a moist state, and free from discoloration. He contrived in such a way as that the water, in falling on the nerve, which he held perpendicularly for that purpose,

pose, should bathe it in every part. To remove every suspicion of any floating particles of the galvanic fluid, he laid the nerve on a very dry glass, before he repeated the galvanization. The movements which are excited in this manner, either cease altogether, or, at the least, become very feeble, if the water simply moistens a point of the nerve, instead of being distributed to every part of it, in its progress to the muscle.

REINHOLD has, as well as many other physiologists, been convinced that galvanism itself augments the incitability of animals. After several feeble movements, he frequently found that others of a powerful nature supervened in a very unexpected way. He observes that they cannot, according to any strict mode of reasoning, be ascribed to a state of repose, experience having demonstrated that the galvanised thigh of a frog, or other animal, displays weaker movements in proportion as it has remained longer in a state of repose, and without incitability, &c. &c.

The next consideration is the incitability depressed by a natural mode, whether physiologically or pathologically. As almost all that concerns the former description, the physiological depression, flows from what has been already said on the subject of incitability physically exalted, there remains but little to be added in this place. There are animals on which, on account

of

of the idiosyncrasy peculiar to them, the incitability of galvanism does not act. Of the very considerable number of frogs dissected by HUMBOLDT, he found about eighty in this predicament. REINHOLD, by whom about two hundred of these animals were subjected to galvanic experiments, found one only which was insensible to the operations. It is the same with the human race: but whether this depends on the state of the body; on the approach of puberty; on the particular state of women at certain crises; on their pregnancy, &c. are points which have not been hitherto decided. It has been observed both by FOWLER and CAVALLO, that the operation of the will may likewise have its share of influence in galvanic experiments.

With respect to the incitability pathologically depressed, the effects are direct and more sensible. The mechanical injury of the nerves and muscles, does not diminish this faculty in any particular degree; a remark which also applies to their division and dilaceration. This is so truly the case, that the muscles, when cut into very small fragments, and the nerves, when divided into very slender filaments, re-act on the galvanic fluid by which they have been incited. BERLINGHIERI was the first physiologist by whom these movements were perceived. After having divided the crural nerves, at their egress from the spinal

spinal marrow, and separated them into filaments of about an inch in length, he laid these filaments, together with the animal itself, on a piece of dried glass, and placed between them a lamina of silver. The movements ensued; but ceased as soon as he substituted to the metal an insulated substance.

Independently of the similarity of the observations made by naturalists, relatively to the nerve bound by a ligature, and the divided nerve, it has also been remarked, that the incitability subsists much longer in the part which is organically united with the divided nerve, than in the one the union of which with the nervous system has been preserved in an entire state. This has been evidently proved in the lower extremities, in the case of which, when the crural nerves have been divided, the movements have been of a much longer duration, than when these nerves were left without injury. The incitable faculty still subsists after the artery has been tied or dissected, but ceases much sooner, under these circumstances, than when no such operation has taken place. Its effects are also diminished much earlier in the part in which the artery has been wounded, than in the one in which a similar injury has been done to the nerve. It is depressed in diseases, as has been noticed by HUMBOLDT, who obtained evident proofs that galvanism does not

not act on persons afflicted by rheumatism. REINHOLD mentions his having ineffectually coated, with the most suitable metals, the tongue of those who were tormented by rheumatic pains, and who acknowledged that they were not sensible of any particular taste in the palate. He adds, that there are certain kinds of death by which the incitability is depressed; and, on this head, adverts to the observations made by several very respectable authors, to prove that it is entirely destroyed in animals killed by gangrene; by hunger; by an exposition to sulphuric vapours; by immersion in water heated to the ninety-sixth degree, and upwards, of FAHRENHEIT'S thermometer; by water in a congealed state; and, lastly, by the shock of accumulated electricity. The irritability of animals is also diminished when their death is occasioned by an exposure to the exhalations of tainted flesh; to those of the nitrous gas, or to the smoke of tobacco. Poisons, and the other causes of the destruction of animal life, produce the same effect.

The subject of irritability depressed by an artificial mode, is next treated by REINHOLD. The acids, more particularly when concentrated; spirit of wine, and oil of tartar, poured profusely on the nerves, together with the solutions of nitre and opium, and certain spirits poured on the tongue, are the artificial agents employed to diminish the incita-

incitability of animals. It has also been noticed by FOWLER, that the muscles are deprived of their irritability, by keeping them for some time immersed in water, after the integuments have been removed. CALDANI makes the same observation relative to the effect of the essential oils of plants, poured on the muscles in a denudated state. Of all the gaseous fluids there is not any one, with the exception of what is denominated by the French chemists carbonated hydrogen gas, which is destructive of incitability. The authors who have adverted to this circumstance, have not been able to ascertain whether the latter gas acts on the muscles or on the nerves.

In speaking of the means by which the incitability is modified, REINHOLD observes, that he has abstained from dividing it into the incitable faculty inherent in the sensible fibre, and that which belongs to the irritable fibre. He has avoided expatiating on each of them separately, because their nature is not as yet sufficiently known, and because it is extremely difficult to demonstrate that the substance which is employed acts rather on the one than on the other, physiologists not having hitherto subjected to their trials a muscle deprived of its nerves. The uncertainty which prevails on this subject, and on several relative ones, together with the discordance of the different authors who have written on galvanism,

vanism, have imposed on him a silence which he cannot forbear to regret.

In his sixth section, in expounding the conditions which are essential in the arc, he considers whether it is always necessary, and what are the parts of the animal it ought to touch. The galvanic phenomena which have been already discussed by him, he observes, are exclusively manifested in the parts of animals, either connected together by an organic union; or reaching to, and touching each other; or, lastly, united in a similar manner to each other, either by other animal parts, separated from the body, or by non-animal substances, with which they form an arc. This the reader must already have seen; and must also have noticed, that when certain substances enter into the composition of the arc, the effect it was intended to produce either ceases altogether, or becomes subject to great variations, in proportion as these substances are displaced. These observations have given rise to several questions, among which are the following. Whether the arc is constantly necessary to the production of the galvanic effects? What is its nature? What substances are the best calculated for its formation? And, lastly, how is it formed by them?

With the exception of Humboldt, physiologists have asserted that the arc is rigorously necessary,

cessary. The former has, however, proved by his experiments, that, without having recourse to it, the galvanic movements can be obtained. This skilful experimenter, in the case of incitable frogs, excited contractions, by touching, at a given point, a metallic substance laid on the crural nerve, with another homogeneous or heterogeneous metal. The contractions became more violent when the former of these substances was forcibly struck by the latter; but ceased when it was struck by a non-conducting body. To remove every suspicion of the formation of an arc, which, by the means of the circumambient air, might have introduced into the nerve the fluid emanating from the metal brought in contact with the nervous coating, HUMBOLDT laid over the metals a bell-glass, from which he excluded the air by the means of oil, taking care to apply it more particularly to the part where the iron wire, by which the metals and the animal were respectively united, passed out of the glass. On this occasion the galvanic movements were displayed as evidently as before.

It is true, that MICHAELIS has expressed his doubts relative to the above experiments; but he appears rather to wish to put those who should repeat them on their guard, than to aim at a refutation. He suspects the existence of an arc, without its having been perceived by HUMBOLDT; in

in reply, to which the latter demands, why the movements are not perceived unless when the metallic substance is made to strike against the coating? and why these movements cease, when, instead of the piece of metal, a substance is employed which has not the faculty of conducting the galvanic fluid? With respect to the explanation he gives of these phenomena, as it is liable to several objections, so it is successfully combated by REINHOLD, who does not, however, offer a better one of his own.

With regard to the parts of the animals which are held by physiologists to be essential in the arc, a great difference of opinions has been entertained. According to GALVANI, and those who have followed him in explaining the galvanic phenomena by the analogy of the Leyden phial, it is required that both the muscle and the nerve should be comprehended in the arc. This opinion, which has been most tenaciously supported by FOWLER, has been demonstrated by PFAFF to be void of any foundation. The latter has shewn, by an experiment, that when the nerves alone are coated, the movements still ensue. Many of the most celebrated physiologists have, accordingly, embraced his opinion.

The parts which constitute the arc, together with their nature and their forces, next engage the attention of REINHOLD. The arc, he ob-

serves, is formed of four parts, namely, of the animal, of the two coatings by which it is touched, and of a conducting substance by which the coatings are connected with each other. VOLTA, in dividing into two classes all the substances which are employed in galvanism, that is, into those which are dry, and those which are moist, was of opinion, at the commencement, that the former excite and give motion to the electricity, while the latter are merely endowed with a conducting property. Having become, afterwards, better acquainted with his subject, he allowed that both the classes are alike possessed of an exciting power. REINHOLD differs from VOLTA, and from HUMBOLDT, in denominating *rings*, or *intermediate and conjunctive parts*, the substances which, being united, form the arc, or chain, as it is called by HUMBOLDT. He employs these terms because they appear to him to denote the substances in question, instead of being purely theoretical.

The physiologists who were the earliest to engage in galvanic experiments, divided the different substances into three classes, according to their virtue and force in the excitement of the phenomena. These substances were arranged in the following manner. In the first class were comprehended those which, being united together, produce the ordinary effects, and which were

were consequently called *exciters*. In the second, those which, being made to supply their place in the arc, do not, in reality, excite the galvanic phenomena, but, at the same time, offer no obstacle to their manifestation. As these substances transmit the galvanic fluid, they were denominated *conductors*. The third class comprehended the substances, which, being inaccessible to the above fluid, at the same time that they support it on its way, destroy the whole of its effect.

This division was afterwards subjected to several variations and additions. The earliest writers on galvanism had comprised in the first of the classes metallic substances only; but charcoal carefully burned, semi-metals, several metallic calxes, certain stones and ligneous substances, together with fluids, have since been added. The employment of these different substances has been greatly varied, according to their combination, and to their application, whether to the muscle or to the nerve. It would be extremely difficult to lay down any precise rules on this head, it being certain that the effect is very different under particular circumstances, and depends on the metal which is employed to unite the humid coatings. On this subject VOLTA remarks, that silver and iron have never produced any effect, without the intervention, in the case of the

 former,

former, of a solution of sulphurated kali, applied to the nerves, at the same time that the muscles were moistened with water; and, in the case of the latter, of a similar intervention of the nitrous acid and water. Reinhold, by whom the same observation was made, found by his experiments, that the metals which are the most efficacious when applied to the nerves, are also the best calculated for the union of the humid coatings. He leaves to others the explanation of the cause from whence this faculty originates.

The discordance of authors relatively to the substances which are inaccessible to the galvanic fluid is very great. Volta, for instance, allows ice to be a conductor of this fluid; while Valli, Fowler, and Humboldt, seem to have demonstrated that it does not possess any such quality. The latter has even gone so far as to prove, that the bones of animals, attenuated air, the flame of a burning substance, and idio-electric bodies, such as sulphur, amber, and glass, in an inflamed state, are conductors of electricity, but not of the galvanic fluid. It is the same with vapours, metallic calxes, stones of several kinds, metallic salts, plants, persons labouring under rheumatic affections, oil, resins, gums, fat, and dried soap. This observation equally applies to atmospherical air, which, being either attenuated or condensed, can never be made to conduct the galvanic fluid; but

but which, on the other hand, being interposed in the formation of the arc, destroys all the effect of the galvanic operation. This has been demonstrated by several experiments.

Physiologists have been much engaged in divining the cause why, among the different substances which have been tried, some have appeared very susceptible of the galvanic influence, others less so, and others not in the smallest degree. REINHOLD recapitulates the different sentiments of authors on this head, and dwells particularly on the opinion of HUMBOLDT, who observes that the galvanic virtue of substances is to be exclusively sought in their electric faculty.

In discussing the modifications of the galvanic forces, resulting from the chemical mixture by which a change is wrought in substances, REINHOLD divides into three classes the changes of this description. The first consists of those which derive their origin from the nature of the bodies, in which a change is brought about in consequence of their chemical mixture having been disturbed. The second class refers to their form; and the third to their union in an arc. Relatively to the substances of the first class, he sets out by speaking of those which are conductors of the galvanic fluid; and afterwards expatiates on those which have a non-conducting quality. The question, whether the different de-

gree of temperature observed in bodies, and which is liable to such frequent changes, establishes, or not, some difference in the cohesion of the parts, has been subject to much dispute. VOLTA maintains that such a difference does really exist; but FOWLER and PFAFF are of a contrary sentiment, assigning to metals in a heated state, powers similar to those, the temperature of which has not been changed. HUMBOLDT reconciles these different opinions, by observing, that the degree of heat which arises from the combustion of metals, is not in reality sufficient to change their nature, but that, when they are only slightly heated, this ceases to be the case, it being demonstrable that they are then possessed of a greater energy. REINHOLD had occasion to notice the truth of this observation; for, having applied, according to the prescribed mode, and at the same time, to several equally incitable frogs, zinc and tin heated to the same degree, he occasionally observed a kind of sportive action between these metals, insomuch that, either successively or nearly so, the one had the superiority over the other in its effects. This result was not only obtained by the means of heterogeneous metals, but likewise, on two occasions, by a recurrence to a lamina of zinc, divided into two parts.

His experiments relative to the changes of the forces of metals, by the friction of certain bodies,

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more especially when moistened, are equally curious and interesting, as they demonstrate that a metallic coating, when very slightly touched by another metal, and that at a single point only, takes the nature of the latter substance. HUMBOLDT obtained the same result, by connecting with the homogeneous coating of the muscle, at another point, and at a very considerable distance, a bit of silver, with which he touched, slightly, and at a single point, a piece of zinc. As a proof, according to REINHOLD, that, in this experiment, the silver had in reality assumed the nature of the zinc, he observes, in the first place, that the lamina of silver, which had not previously excited any contraction, excited very powerful ones, when, its two extremities, having been rubbed by the zinc, the muriatic acid with which the muscles were coated, was united with the deliquescent oil of tartar placed beneath the nerves; and, secondly, that the above lamina of silver, being brought in contact with the nerves, produced very powerful movements; but was not productive of the slightest contraction when it was applied to the muscles. From whence these effects, as well as several others which REINHOLD recapitulates, originate; and how a metal which is touched receives the influence and the energy of the metal which touches it, are questions which have not been defined, any more than the changes of

the powers of the exciting arcs, when blended with each other.

The influence of the form of the exciting arcs on the galvanic phenomena, is next considered by Reinhold, who denies that the faculty of changing the effects can be assigned, as Fowler asserts, to the thickness of the exciting arcs. It has been, he observes, experimentally demonstrated, that a metallic substance, covered with a heterogeneous plate of metal, produces, in galvanic processes, merely the forces inherent in the metal which is employed as a covering. Those who contend that, in proportion to the size of the coatings, the galvanic phenomena are remarkable, have been also led into an error. It has been clearly proved, both by Galvani and Humboldt, that the greater or smaller dimensions of the coatings of the nerves, have no degree of influence in changing the galvanic phenomena.

On the subject of the different galvanic phenomena produced by the diverse arrangements of the arc, Reinhold is of opinion that the changes which result from the assemblage of the substances formed into an arc, spring from two sources, the first of which consists in the place where these substances are stationed in the arc, and the second in the mode of arranging them. He thinks that the arc ought to be so arranged

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as to embrace the nerve itself; and that it should be entirely composed of exciting substances, without being intercepted by any non-exciting body. The mode of distributing the two coatings in the arc is by no means indifferent: or, in other words, it is not the same thing to place one of them beneath the nerve, and the other beneath the muscle, or to follow, in stationing them, a contrary order. According to the observations of the most skilful naturalists, any exciting substances whatever, whether dry or moist, are extremely efficacious when one of them is applied to the nerve, and the other to the muscle. As soon as they are brought in contact, or united with other exciting substances, very singular galvanic phenomena are displayed. But when they are disposed in a contrary order, these phenomena either cease, or are diminished in a greater or less degree, and do not, in the former case, again manifest themselves until the coatings are reciprocally withdrawn from each other. It has not hitherto been discovered to what cause this characteristic of exciting substances is to be ascribed; and, indeed, physiologists are not as yet agreed as to their mode of action. VOLTA asserts, that the coating applied to the nerve gives a forward impulsion to the electricity, which is attracted by the coating of the muscle. BEN-

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NETT's doubler appears, however, to have proved that this cannot be true.

REINHOLD classes under several heads the arcs he employed, and explains his theory by tables, which are not inserted here, because the subject will be fully explained in the sequel of this work. He points out the different descriptions of arcs, and the form of each of them, to give a comprehensive idea of the effects they produce in galvanism. After having demonstrated the mode in which the effect is changed, by the places which the different substances occupy in the arc, he shews how it is also changed by the manner of connecting the different substances. He observes that, should there even be a deviation, in repeating his experiments, from the rules he has laid down, they would, nevertheless, be attended by a successful result, seeing that it is of little importance whether a long or short, thick or thin, compound or simple, connecting body, be employed. It is equally unimportant whether the dry coatings, whatever their dimensions may be in length or in thickness, be contiguous to each other, or to the connecting body. But on the other hand, when humid coatings are employed, the effect constantly decreases with their augmented length. Several instances of very long arcs have been given by different authors, who

who have proved that the galvanic fluid is conducted equally well by arcs formed of animal parts, or entire animals, superadded to the coatings; by a single person, or by several; by very long wires of different metals; by very long humid cords; and by very abundant fluids. ALDINI has employed cords of two hundred and fifty feet in length.

REINHOLD, who is apprehensive that he may be accused of having, in speaking of the movements, confounded those which arise from the sensations, observes that he is, in common with many other naturalists, persuaded that they are derived from the same source with the other movements, insomuch that what has been said of the one description may be applied to the other. In support of this doctrine he brings forward the following proofs: In the first place, that they both originate from the same conditions, and are excited by similar substances, applied in the same manner to the same animal. Secondly, that whatever deranges either of them, produces a change in the other. And, lastly, that they frequently take place at the same time, by the means of the galvanic apparatus, in the same animal, and in the same organ. He afterwards enters into a brief exposition of the particular forms of the arc by which the galvanic pheno-

phenomena are alike produced in each state of incitability.

Researches have been made by HUMBOLDT, to ascertain whether, when the arc has been formed in any given part of an animal, the galvanic phenomena might be produced by the means of another arc established in the same part. He is not only convinced that this may happen, but also that the second arc, if formed of more efficacious substances, would predominate over the first. REINHOLD observes, that he has not, in every instance, found it necessary to recur to more powerful substances; and that, by employing a second arc, composed in the same way with the first, he has frequently given birth to new commotions, &c. After repeated experiments on this subject, with two arcs of a different nature, it has been demonstrated that the movements have been excited, sometimes with the one, and sometimes with the other, according to the circumstances.

The seventh section of REINHOLD's dissertations is devoted to considerations on the nature of the galvanic fluid, and sets out by an inquiry whether this fluid acts on the organized parts of animals, after the manner of mechanico-chemical *stimuli*. As there is no one who, after all that has been hitherto said on the subject of galvanism, does

does not comprehend that its phenomena ought to be classed among those which ensue when the organized parts of animals are put in action; and likewise that these phenomena are infinitely more active when certain substances, formed into an arc, are applied to the animal; the following questions will necessarily be asked: *What is this excitement? Does it arise from the animal, or from the arc? What is its nature? And what are the laws it follows?* Such are the questions which REINHOLD proceeds to discuss.

Relatively to the first of them, he defines what he calls the agent, the excitement, *incitamentum*; and which, according to him, is a body applied to a living and organized part, by which this part is made to re-act on itself, according to the laws Nature has established. This agency he classes under three different heads, *mechanical, chemical*, and *mixed*. He entitles *mechanical* the one which, being found in the animal in any manner whatever, disturbs in a greater or less degree, without, however, bringing about a direct change in their nature, the situation and natural union of the elementary parts, by mechanical powers, by their specific gravity, by their mass, and by the celerity which this agent communicates to them. He denominates *chemical* agent, the one which, being applied to the above parts, acts by its affinity with their constituent elements, and which some-

sometimes affords products, sometimes subtractions, and sometimes both. The *mixed* agent he makes to consist of the combination of the two preceding ones, when, in consequence of the derangement of their parts, they operate, either by mechanical, or by chemical forces, according to their nature; and when the parts, disunited by these forces, are subjected to the one or to the other of the particular changes, which may sometimes be called *mechanico-chemical*, and at other times *chemico-mechanical*. Agents of this description have been entitled by authors *physical*; but REINHOLD is fully persuaded that the name of mixed is better suited to them.

His next inquiries are, whether the agent by which the galvanic phenomena are excited, is properly entitled *fluid*; and what is its nature. He regards the galvanic fluid as particular, as differing from all others, and as having a nature appropriate to itself. He endeavours to prove, in the first place, that it does not belong to either of the kinds of factitious air. Secondly, that it is not magnetical, has been evinced by the observations of FOWLER, CREVE, PFAFF, and HUMBOLDT, who have found that, in galvanic experiments made with the magnet, no other effects were produced on the animal than those which are brought about by a non-magnetized iron. Lastly, the great majority of naturalists have considered the

the galvanic fluid as identical with the electric fluid, and have conjectured it to issue, according to some, from the animal, and according to others, from the arc. Several of them assign its cause to common electricity; and others to a modified electricity, changed in the animal by the vital force. After having detailed the reasons and experiments on which the similitude and the relation of the galvanic and electric fluids are established, REINHOLD relates those also, of an equally powerful nature, by which this similitude and this relation, are destroyed. He shews that the laws by which the galvanic fluid acts, are very different from those followed by electricity; and concludes, with HUMBOLDT, that as the galvanic fluid, when compared with the electric fluid, has its accordances and its differences, there are elements which, by a kind of mixture and intermarriage with each other, sometimes produce the electric fluid, sometimes the magnetic fluid, and at other times the galvanic fluid.

Whether the galvanic fluid is secreted in the animal, is next considered. REINHOLD deduces the proof that this fluid flows from the animal, from the circumstance of the contractions excited when an animal part unites the muscle with the nerve. These contractions also ensue when the dissected nerve is brought in contact with the

the part to which it belonged; and this likewise happens when the muscle has been gently brought over the nerve with which it is organically united, without the process being attended by a discharge of blood, or of any other humour. These experiments, in the opinion of REINHOLD, are calculated to remove every suspicion that the fluid is not innate in the animal organization. He observes that it differs according to the class and nature of animals, and that its secretion belongs exclusively to animated beings. The galvanic fluid accordingly appears to be formed, in the body of animals, of elements calculated to excite in the nerves motion and sensation. It has been ascertained by the observations made by naturalists, that each organ has the faculty of secreting the fluid necessary for the exercise of its functions; but that the nerves alone, and not the other parts of animals, possess the power of secreting the galvanic fluid. If, however, attention be paid to the effects which result from the combination of the irritable fibre with the sensible fibre, it will appear that the elements of this fluid are constantly and invariably the same. It may indeed be modified to such a degree, as to lead to a conjecture that when it resides in the muscle, it deviates in some measure from its primitive state in the nerve itself.

All those by whom galvanic experiments have been

been made, have acknowledged that the galvanic phenomena are modified by the application of the arc to the animal. REINHOLD directs his inquiry to the mode in which this is effected. However fully he is persuaded of this modification in the arc, he expresses his doubts relative to the quality which has been changed; and, without endeavouring to remove this difficulty, proceeds to consider the direction of the fluid circulating in the arc. It would appear by the galvanic phenomena, that this direction is invariably the same; for, independently of the savour which remains on the tongue, and of the throbbing pain which HUMBOLDT felt three or four times, after having applied the arc to parts which had been blistered, the painful sensation in question proves; by its return, the constant presence of the fluid. So long as the application of the arc continues to be made, the pain subsists, diminishing in proportion as the incitability is enfeebled, and becoming more acute when this quality is excited by the means of oil of tartar. Several experiments are cited by REINHOLD, which prove that the galvanic fluid does not possess the same faculty of excitement throughout the whole extent and compass of the arc. They also demonstrate that this fluid may proceed in the nerves in an ascending, as well as in a descending direction; but that, as it descends with greater facility, the

galvanic phenomena are most powerful when that route is followed.

In the recapitulation of his opinion of the galvanic fluid, REINHOLD enters into an explanation of several of its phenomena, and, among others, describes the mode in which the nerves act, in the production of movement and sensation. He also points out the manner in which the contractions take place, in an organized part extracted from an animal, and prepared according to the method which has been described; as well as the cause of the galvanic phenomena that ensue, when the coatings are reciprocally withdrawn from each other. After having entered into several explanatory details relative to the experiment of the ligature made on the muscles of frogs, and to the application of the coatings, he concludes the present section by the following observation, with which he endeavours strongly to impress his readers; *that the galvanic fluid, if its existence be granted, is of a different nature from the electric fluid, and that it is exclusively supplied by animated beings.*

The subject of the eighth and last section of REINHOLD's Dissertations, consists of the exposition of the hypothesis of different authors on the galvanic fluid. These hypothesis he brings into two classes, as they relate to the seat which is assigned to the cause of the phenomena.

mena. The first of these classes belongs to the animal which is to be galvanized; and the second to the substances applied to its body, or to the arc. As the galvanic phenomena are ascribed by several physiologists to electricity, REINHOLD makes a new division, relatively to the opinion of those who assert that the galvanic and electric fluids are the same, and of those who are persuaded that the former differs from the latter. Under the first head, or division, he ranges GALVANI, ALDINI, VALLI, CORRADORI, VOLTA in the early time of the discovery, SCHMUCK, VOIGT, and HUFELAND; and under the second, FOWLER and HUMBOLDT. Of the latter division he makes subdivisions, in the first of which he comprehends VOLTA, PFAFF, WELLS, YELIN, and MONRO; and in the second, CREVE and FABRONI. The other authors not having openly avowed their opinion, he passes over in silence.

It is not necessary for us to follow him in the exposition he makes of the sentiments of the above authors, because, in continuing to give a particular account of their works, we shall speak, at the same time, of their doctrine, and of the different hypotheses they have entertained relatively to the nature of the galvanic fluid, as we have already done in the case of GALVANI and others. The analysis we have made of the

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very learned dissertations of Reinhold, will lead to a thorough comprehension of what is to follow, in the subsequent parts of the History of Galvanism we have undertaken.

CHAP.

PART II.

CHAP. IX.

On the irritation of the muscular fibre—Relation between galvanic irritability and incitability—Galvanic experiments made on the different classes of animals with various substances—Letter of VASSALLI EANDI *on the phenomena of the torpedo.*

THE production of the celebrated HUMBOLDT, entitled "Experiments on Galvanism, and, in general, on the Irritation of the Muscular and Nervous Fibres," comes next under consideration. The frequent references which have been made to the researches of this naturalist, must have inspired our readers with a wish to become fully acquainted with a work of so distinguished a merit.

The appellation of galvanic phenomena has been bestowed on the property, observed in the nerves of animals, of being irritated by metallic substances, by substances containing charcoal, and even by the contact of living organs. By

this irritation the very manifest contractions and movements in the muscles, or in the organs provided with muscular fibres, are excited, when the parts in question are subjected to galvanic experiments. The greatest advantage wnich has been hitherto derived from this irritation, when employed in the examination of the structure of insects and worms, consists in the discovery of a nervous system, before unknown, in several of these animals.

If it would be a vain pretension to attempt to explain, by the influence and effects of galvanism, all the phenomena of the nervous system, it is, notwithstanding, incontestable, that this discovery has contributed essentially to the knowledge we had already acquired relatively to the nerves. It has done still more, by supplying us with the happy idea of its application to medicine; an idea founded on its having been sometimes successfully employed in restoring to life animals apparently dead from asphyxia. The different agents calculated to produce, on the nervous action, any influence whatever, must naturally excite the attention of physiologists and medical men. It is now placed beyond the reach of any doubt, that galvanism is one of the most powerful agents of this description.

In this publication before us, HUMBOLDT sets out by developing the results of his experiments,

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and by giving an exposition of the simple and convenient forms by which he has contrived to express them with all possible brevity. The principal basis of these forms consists in the well-founded distinction of substances, so far as they relate to galvanism, into *exciters*, consisting of metals in general, as well as all substances which contain charcoal; and into conductors, comprehending humid substances of every description. At the time when HUMBOLDT's work appeared, its author had already obtained from his experiments the fullest conviction that the effects of galvanism are not ascribable to electricity. He accordingly attributes them to a fluid inherent in living animals, which fluid he conjectures to be analogous to magnetism and electricity.

The earliest experiments undertaken by M. HUMBOLDT were made in the presence of M. VENTURI, Professor of Natural Philosophy at Modena, and several medical students. The brain and spinal marrow of several frogs having been denudated, and the animals properly armed, powerful contractions were produced, by the application of the galvanic arc, in the muscles of the thorax and abdomen, together with slight contractions of those of the thigh. Violent convulsive movements of the eyes were at the same time perceived. The diaphragm, a muscle which is in all cases extremely sensible to galvanic irritation,

was also powerfully contracted. As soon as the femoral and sciatic nerves had been irritated, violent contractions were produced in the thigh. The experiments on the heart and stomach were attended by but little effect. When, however, they were made on the heart of a dog, separated from the animal, and which had ceased to contract, the contractions were, in a certain degree, renewed; and, in the case of the stomach, a feeble motion was induced in the parts touched by the zinc. These experiments were afterwards repeated with pretty nearly the same results.

As the efficacy of the different substances calculated to bring about the galvanic phenomena, and the modifications they induce, had attracted the attention of naturalists much more than the effects of galvanism itself on the animal economy, HUMBOLDT determined to direct his experiments more particularly towards that aim. The cause of galvanism appearing to reside in the body of living animals, and to be merely excited to action by extraneous substances, he was of opinion that the strongest light would be thrown on this subject by the observation of the phenomena the animals should present. Now, seeing that the magnetic and electric fluids, which are neither peculiar to the living body, nor secreted in its organs, as the galvanic fluid appears to be, have, notwithstanding, a decisive influence on the human

man body, as well in a healthy condition as in a diseased state, ought it not to be concluded that galvanic researches are equally interesting to the physician and to the naturalist, insomuch that the former has a right to hope that galvanism may one day be usefully employed in the cure of particular diseases? What has been practically done on this head by different physiologists and professional men, will form the subject of a future chapter of this work. In the science of galvanism, as well as in every branch of natural philosophy, facts alone are stable and certain.

The following are the conclusions drawn by HUMBOLDT from his early experiments.

1st, That the effects of galvanism are almost invariably different on the diverse parts of animals; and that multiplied and well combined experiments on this subject may furnish a tolerably correct appreciation of the respective forces of the different extensor and flexor muscles.

2dly, That in animals with warm blood the diaphragm is, of all the muscles, if not the most powerfully, at least the most easily irritable, it being the only one which constantly contracts with violence in the experiments without a chain. This may lead to a knowledge of the respective degrees of irritability residing in the different muscles.

3dly, That the living nerves and muscles are surrounded

surrounded by an active and sensible atmosphere; and that the action of the nerve extends beyond the points at which they are distributed.

4thly, That galvanism is capable of exciting movements in the organs which are altogether independent of the will, such as the heart and stomach.

5thly, That the galvanic fluid proceeding from an animal with warm blood, may act efficaciously on the human nerves.

6thly, That the galvanic phenomena take place without the intervention of any external body; which proves that the cause by which they are produced resides in the living animal economy.

7thly, That these phenomena may be made apparent by the means of a chain established between two points of one and the same nerve, as well as in the organs brought in contact with any part of the chain.

8thly, and lastly, That by the discovery of galvanism, anatomists are supplied with the means of ascertaining, in small animals, the nervous distributions which are too minute for dissection.

From a comparison between many of the phenomena of living bodies with those of dead matter, HUMBOLDT conceived the idea of instituting a series of experiments by which vitality should be, as it were, subjected to a chemical analysis.

analysis. He thinks it by no means impossible to prove that the irritability of the constituent parts is not solely ascribable to oxygen, as several modern physiologists have apprehended, but that azote and hydrogen contribute greatly to this property of the animal fibres, which seems principally to depend on the reciprocal action of these different principles.

The galvanic phenomena constitute his earliest inquiry, because he flatters himself that his experiments have enabled him to prove incontestably, that in these surprizing phenomena the stimulus arises in a great measure from the organs, which cannot, on that account, be considered as merely passive. Laying aside every theoretical prejudice, in investigating the subject he has in view, he gives such a direction to his experiments, as if he meant to prove the very reverse of the hitherto received principles relative to metallic irritation. He states separately, and in the order in which they presented themselves, the observations he made during three years, as well on this subject in particular, as on metallic irritation in general.

His attention having been drawn aside by occupations of a very different nature, he did not think of publishing these observations, until the work of our countryman FOWLER, on the galvanic influence, enlightened him as to the result of his experiments, which he had hitherto apprehended

hended to be peculiar to himself, at the same time that similar ones were made by other naturalists, such, for instance, as the experiment of Mr. G. HUNTER, of York, which consists in perceiving the flash of light without any contact of metals with the eyes. HUMBOLDT now began to collect all that had appeared on this subject from the origin of the discovery, and to compare this information with what he had himself observed. On reading the excellent production of PFAFF on animal electricity and irritability, he found, in the very considerable number of experiments it contains, and in the important observations by which they are accompanied, results exactly similar to those with which his own experiments had supplied him, notwithstanding a very different mode of investigation had been pursued by their author. He was now obliged to renew his labours, and to suppress the one half of his experiments. By the observations of Messieurs JURINE, PICTET, SCARPA, TRALLES, and VOLTA, in whose presence they were made, he corrected his ideas; and their reflections conducted him to new researches. After having collected all the observations on irritation, and on the incitability of the sensible and irritable fibre, he began with the history of galvanism, as it led to the other researches. Finding it unnecessary to go into any length of detail, in penning down his observations, the results alone being of importance, he has contented himself

himself with pointing out the principal ones, in
loose way, and in the order in which they pre-
nted themselves to him. His work is divided
to ten sections, which, after the introductory
atter already given in substance, form a kind of
ble of the subjects they discuss, and of which
e following is a brief, but faithful analysis.

In the first section the author expatiates, in
neral terms, on the relation between galvanic
ritation and incitability, and on the different
egrees of the former, which, he observes, acts
xclusively on organic parts provided with sen-
ible fibres. The indirect effects on inanimate
atter, connected with incitable bodies, have
ot as yet been experimentally demonstrated.
HUMBOLDT, with great care, and with an extreme
ttention, caused the galvanic fluid to pass
hrough coloured liquors, and through other
quors saturated with salt. These experiments
e repeated with great assiduity, but could never
bserve the smallest alteration in the colour, tem-
erature, *evaporability*, or crystallization of the
uids in question, in the chemical combination of
hich he could not perceive the smallest change
have been wrought. It did not produce any
nsible effect, either on the electrometer, or on
e intermediate rings of the galvanic chain, so
to indicate its strict analogy with the electric
uid.

In his investigation of the effects of a metallic
stimulus

making any other alteration, a bit of brass wire was substituted to the glass tube by which the portion of flesh had been brought in contact with the thigh. Notwithstanding the metallic part did not, at the above time, enter into the metallic chain, it had a powerful influence on the galvanic phenomena. It was even noticed by HUMBOLDT that contractions ensued when the mode of connexion was formed by animal parts heterogeneous to the nerves. When he brought the crural nerve, detached from the trunk conjointly with the thigh, towards the latter part, or retracted it, on the other hand, he failed to produce any convulsive movements; but they became very violent when the muscular flesh of the hip was gently laid over the sciatic nerve, still connected with the trunk.

The third section of HUMBOLDT's work treats of the excitement produced by a simple metallic substance, or by homogeneous metallic parts. He examines the phenomena which have been the most scrupulously observed, and which, in consequence of their being more complicated than the others, have been discussed and combated with the greatest obstinacy. They take place in the highest degree of excitability, and consist of the contractions produced by metallic substances, or substances containing charcoal. These phenomena are reduced by HUMBOLDT to an inconsiderable

siderable number of simple facts, by the distinction between two principal cases, namely, the irritation produced by homogeneous metals, and the one produced by heterogeneous metals. He divides the former into those which form a complete chain between the animal organs, and those by which such a chain is not established. He next details the result of his experiments on this head, as well as of those made by ALDINI, GALVANI, BERLINGHIERI, LIND, PFAFF, and VOLTA, terminating the section by an experiment which appeared to him very conclusive, relatively to homogeneous conductors.

"Two frogs," observes HUMBOLDT, "were before me, the thighs of which, when the coatings of zinc and silver were applied, displayed very feeble contractions. I moistened the crural nerve of one of them with a solution of the carbonate of potash, and that of the other with the oxygenated muriatic acid. To my great surprize, there were not any contractions when a coating of silver, which had been applied to the muscle, was brought in contact with a coating of gold applied to the nerve. I broke into two portions a small bar of well purified zinc, and, having laid the nerve on one of these portions, the instant I brought it, by the help of the other portion, in contact with the muscle, powerful contractions were excited. Three thighs of frogs,

treated in this way, presented the same phenomena for the space of several minutes. Can it be supposed (adds HUMBOLDT) that two portions of the same bar of zinc should be less homogeneous than silver and gold? The question of homogeneity, in exciting substances, proves that there are, as well in physics as in chemistry, many cases in which the observations present contrarieties. The circumspect observer by whom this is witnessed, remains undecided and dissatisfied."

In the fourth section HUMBOLDT speaks of heterogeneous metals. To the end that these metals, as well as all the substances containing charcoal, may produce galvanic phenomena in an exalted state of the excitability of the organs, it suffices that they form a part of a series of conducting substances, established between the sensible and irritable organs, whatever may be the length of the chain they form. This is proved by a great number of experiments cited by HUMBOLDT in the present section. In these experiments he was engaged, in concert with his elder brother, when chance led him to a very interesting discovery. He found that the coatings of the nerve and muscle being homogeneous, the contractions may be produced when the degree of excitability is extremely feeble, provided the coatings of this nature are united by exciting substances, among which there is a heterogene-

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ous one, having one of its surfaces covered by a fluid in a state of vapour. This observation was made at the commencement of 1796, and surprized HUMBOLDT so much, that he instantly communicated it to SOEMMERING, BLUMENBACH, HERZ, and GOETHE. He had not at that time, in the works on galvanism which had already appeared, met with any experiment the result of which had the smallest analogy with his discovery; and it was not until after the publication of the work of PFAFF on animal electricity, that he became acquainted with any one similar to his own. There were, however, some differences, as he proves by several passages cited from the above author.

In the four sections the substance of which has been given, our author, in explaining the circumstances which tend to the production of the galvanic phenomena, as well as those which lead to their failure, observes that he has scrupulously avoided to confound the facts with the conjectures to which they gave rise. In the fifth section he explains the signs he has adopted, to represent all the conditions of galvanism, together with the forms he has employed to express the positive cases and the negative cases, relatively to which latter, he observes, the utmost caution ought to be observed in the consequences drawn from the experiments. He distinguishes, in gal-

vanism, two classes of active substances, the former of which comprehends metallic substances of every description, together with charcoal, and the substances into which it enters as a principle. The second class comprises all moist animal and vegetable substances, muscular flesh, water, wetted cloth, &c. The former of these substances have been generally denominated *exciters*, and the latter, *conductors* of the galvanic fluid. Our author observes that this division of substances is false, and in absolute contradiction to many of the experiments he has made. He therefore rejects, in his formules, these denominations, which he considers as purely hypothetical.

To have a clear and comprehensive idea of the full extent of the galvanic phenomena, it is not sufficient to consider, in a general way, all the circumstances by which they are determined; it being also essential to examine the modifications they present, in the different classes of animals. This, together with the consideration of the substances which are, in the greater number of cases, necessary to the production of the galvanic phenomena, are the subjects of the sixth section. Metals in a state of regulus, carbonated and sulphurated metals, the oxyde of manganese, the only metal the combination of which with oxygen is fully possessed of the conducting property

of

of the galvanic fluid, sea-coal, charcoal, the carbonated sulphurate of zinc, plombago, the Lydian stone, the aluminous and sulphuric schists, water, and all liquids, with the exception of oil; —such is the list of the metals and carbonated substances, which, whether alone or conjunctively, are deprived of the property of conducting the galvanic fluid, the instant they are surrounded either with oxygen or hydrogen.

At the time when HUMBOLDT's work appeared, very few experiments had been made by other physiologists, on the comparative effects of animal and vegetable substances employed in the galvanic chain. On this subject he made several precise experiments, of a very curious and instructive kind, more especially on the epidermis both of animals and vegetables. Having, in the course of these experiments, composed a chain of seven or eight persons, he occasionally remarked that the movements of the muscles did not ensue, until one of them, who constituted a part of the chain, quitted it. He adds that, on several of these trials, he could not discover the non-conducting individual, until all the persons who composed the chain had withdrawn from it successively. There were instances in which this individual wetted his hands ineffectually, and without bestowing on them the conducting property, although, under other circumstances, this

 expedient

expedient was found to be highly efficacious, as was also that of sprinkling the floor on which the chain was established.

The following very interesting phenomena is, in HUMBOLDT's opinion, a fit subject for the exercise of the sagacity of physiologists. Every one is acquainted with the sensation denominated *the setting of the teeth on edge*, which is produced by the action of weak vegetable acids contained in grapes, plums, apples, lemons, &c. The whole of the crown of the teeth, particularly the enamelled substance, which is insensible in its ordinary state, then becomes so sensible to impressions, that the contact of a piece of woollen or linen cloth, or of cork or brown paper, and even sometimes the mere *dread* of the contact of these substances, produces, according to HUMBOLDT, a very disagreeable sensation. The attention of naturalists was first attracted to this subject by Dr. WEDEKIND, of Mentz; and it has been since discussed with great sagacity by REIL, the celebrated physiologist of Halle. What, indeed, can be more singular than to see a part of our body, the substance of which is principally terrene, and to which Nature seems to have denied every share of sensibility, acquire one of so lively a nature, when touched by an acid? It is known that VOLTA's experiment does not succeed, if, instead of applying the coatings, the one of silver, for

instance,

instance, and the other of zinc, to the two surfaces of the tongue, one of these metals be laid on the crown of the teeth, while the application of the other is made to the tongue. HUMBOLDT being desirous to know whether the teeth still possess this insulating property, in the state in which they are said to be *on edge*, and whether there was any foundation for the opinion of WEDEKIND, by which he had been led to think that the contrary is the case, found the ideas of that naturalist fully confirmed by the experiments into a detail of which he enters.

Relatively to the existence of sensible fibres in the tendons and ligaments, REIL adopts the pathological facts collected by WHYTE and MURRAY, by which the sensibility of these parts is brought forward in evidence. HUMBOLDT is, on the other hand, persuaded, that the result of several experiments made by him, is such as to justify his doubts as to the fidelity of these assertions; and the reasonings and proofs he adduces in support of his experiments, seem to demonstrate that his inferences are not improperly drawn.

His attention was directed to mushrooms, with a view to ascertain, whether, in consequence of their substance having a great analogy to that of animals, they possess a conducting property, similar to the one which resides in the muscular

 flesh.

flesh. He accordingly made a considerable number of trials, the results of which were, that the different kinds of mushrooms, which, in becoming putrid, emit an animal, insipid, cadaverous smell, are as perfect conductors in the galvanic chain, as the organs of animals. The morels, and more especially the three kinds which are eaten, namely, the *phallus esculentus*, the *elvella mitra*, and the *elvella sulcata*, are strongly possessed of this quality. On this head HUMBOLDT remarks how essential it is that chemists should direct their researches to an analysis of the different descriptions of mushrooms, by which they cannot fail to make many important discoveries. He cites the researches of GUNTHER, undertaken upon his suggestion, on the *agaricus campestris*, in which was found a great quantity of sugar susceptible of crystallization.

Having thus described the simple and compound substances which produce the galvanic phenomena, when brought in contact with the excitable organs, HUMBOLDT, in his seventh section, describes, in a tabular form, the conducting substances, and those by which the galvanic fluid is insulated. With respect to the conductors, he observes that, when the coatings are applied, in a direct and immediate way, both to the nerve and the muscle, the length of the conductor does not appear to be limited. VALLI having

ing employed conductors of two hundred feet in length; and ALDINI having carried very long cords, made with moistened hemp, round his house at Bologna; the experiments in either case succeeded perfectly well. HUMBOLDT adds, that conductors of 19,200 feet, similar to those which were resorted to in the electrical experiments of JALLABERT, SIGAUD DE LA FOND, MONNIER, WATSON, and WINCKLER, may be employed. He is even of opinion that this extent may be prodigiously augmented, by having recourse, for example, to rivers as conductors.

In the employment of very long conductors, it was not possible for HUMBOLDT to remark any interval between the instant when the muscle contracts, and the one when the contact of the conductor takes place, the muscle and nerve being from two hundred to three hundred feet distant from each other. This announces a celerity of twelve hundred feet per second. The effect would be the same, should the conductors even be from ten thousand to twenty thousand feet in length. Thus HALLER, in his physiology, ascribes to the nervous fluid a swiftness sufficient to enable it to run over a space of nine thousand feet in a second. The calculation of SAUVAGES is carried to thirty-two thousand four hundred feet in the same space of time; and, what is still infinitely more surprizing, its celerity is estimated

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by the author of the essays on the mechanism of the muscles, at five hundred and seventy-six millions of feet, (upwards of one hundred thousand miles) in the above space of a second of time. It ought here to be noticed, that the great differences in these calculations arise from the different kinds of experiments on which they are founded.

It was reasonably to be expected that galvanic experiments should, as well as chemical analysis, furnish certain elucidations relative to the nature and combination of matter. In reality, the living nervous fibre serves, as well as chemical reacting substances, to determine the nature of certain bodies. It has been long known that a divided nerve acts as a living hygrometer; and it has also been noticed, that persons endued with great sensibility, feel a strong impression when a change takes place in the temperature of the atmosphere, as well as on the approach of a storm. This proves that the human body acts both as a thermometer and as an electrometer. SOEMMERING has explained, with great ingenuity, the disagreeable sensation which is occasionally felt, on any change of weather, in the case of a limb having been amputated. He is of opinion that the humidity which the extremity of the nerve absorbs from the air, by compressing the nerve itself, is the cause of the pain, which continues

until

until the humidity has been dissipated by a dry atmosphere.

The following experiment, which was frequently repeated by HUMBOLDT, notwithstanding it is merely of a recreative kind, ought not to be passed over in this place. By applying a flattened piece of zinc to one of the surfaces of the tongue, and a flattened piece of silver to the other surface, without either of these coatings touching the other, but each of them provided with a long iron wire; and by passing the wires, in a parallel direction through a door, behind which they are brought together and separated alternately; the person who makes the experiment ascertains, by the taste he feels on the tongue, the situation of the extremity of each of the wires.

A phenomenon which, fifteen years ago, would have been considered as chimerical, has likewise resulted from the experiments on the galvanic fluid. It is as follows: A nerve, organically united with several cubic lines of muscular flesh, indicates whether two metals are homogeneous or heterogeneous; and whether they are in a state of pure regulus, or in an oxydated state. It also points out whether the coloration of a mineral substance depends on charcoal, or on an oxydation which has taken place. The living nervous fibre is consequently a living *anthracoscope*, a mean of discovering charcoal, almost

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as certain as the action of iron, and that of alkalis.

Conformably to the result of his experiments, HUMBOLDT replies affirmatively to the question, whether the muscular movements and sensations produced by galvanism are prolonged after the chain has been closed. Among the experiments which he cites, he informs his readers that, in his own case, he applied two blisters to each of the deltoid muscles. This was an effort which required no small share of courage*. One of the wounds was covered by a large silver medal, and the communication established, by the means of zinc, between the two wounds. The result of the contact was, that the muscles of the shoulder and of the neck contracted alternately; and, in addition to this, our naturalist felt a violent smarting sensation, as soon as the bladder formed by the vesicatory was opened. He could clearly distinguish three or four small, simple bodies; and it frequently happened, that two of these small bodies were not productive of any sensation, until after the zinc had been laid for

* This may truly be said, when it is considered that HUMBOLDT had made a similar application several times, in different circumstances, to ascertain the effects of his galvanic experiments. It will be seen hereafter, that he was still more courageous when he undertook to denudate one of his nerves.

some time on the true skin in its denudated state. What proves that the force of the phenomena depended entirely on the degree of incitability residing in the organs, is, that the ulcers having been exposed to the air for the space of half an hour, and the *rete mucosum* having become indurated, a single contact would no longer produce any more than a single contraction. When a few drops of an alkaline solution had been poured on the coating, the incitability of the organs was instantly augmented in a powerful degree. The pains became extremely violent; and HUMBOLDT perceived, at the same time, that the contractions were renewed, and succeeded each other three or four times consecutively. It is true, that they lasted for one or two seconds only; but the smarting sensation was prolonged uninterruptedly, and in the same degree, so long as the coatings remained in contact.

In examining what passes in animated conducting substances, after having refuted the error of those who think that the metallic irritation merely acts on the organs to which the coatings are immediately applied, HUMBOLDT gives it as his opinion, that an unknown fluid pervades every part of the galvanic chain; but that its exciting property is manifested more powerfully on the organs which are immediately coated, than on those which are at a certain distance from the

coatings,

coatings, in the case even of the latter being equally excitable. This opinion he supports by observations which appear to him to be conclusive. An individual who entertained a strong belief of the cures performed by magnetism and electricity, assured our naturalist that he invariably felt a peculiar sensation of warmth, as often as he formed a part of the galvanic chain. HUMBOLDT caused to be removed, without his perceiving it, both the metallic coatings and the prepared animals. The sensation of heat continued; and was become still more powerful when he assured this person, with an assumed air of gravity, that he had employed, in the chain, new means of a more efficacious nature. Is it surprizing, after this, that *perkinism* should have its partizans and admirers, as was formerly the case with the now justly exploded doctrine of MESMER?

The experiments made by HUMBOLDT on the nerves, demonstrate that a stimulus arising from those of cold-blooded animals, is capable of irritating those of animals the blood of which is warm; but that this irritation follows different laws, according to the nature of the organs of which the chain is composed. The considerable number of experiments, published by different authors, on the ligature of the nerves, and that of the arteries distributed in the muscles; together

ther with those made both on cold-blooded and hot-blooded animals, have caused it to be considered as a fixed and invariable principle, that the ligature does not interrupt the galvanic effects, whenever the portion of the nerve, comprehended between the muscle and the ligature, is surrounded by an insulating body.

The discussions which had taken place relatively to the ligature of the nerves and arteries, inspired HUMBOLDT with the idea of instituting experiments on the sensible fibres divided into two portions. In this way he was enabled to discover the property innate in the living sensible fibre, of acting at some distance, and of dispersing around it an irritable atmosphere. This property is of the utmost importance, in the explanation of several physiological and pathological phenomena. He confides to skilful anatomists the charge of making the numerous applications of which it is susceptible; and contents himself with examining such of the phenomena of this description, relatively to the sensations of touching and of the taste, to the re-production of the nerves, and to several sympathetic effects, as have appeared to him most deserving of attention. His experiment relative to irritable and sensible atmospheres is extremely curious and interesting. On this subject we shall touch hereafter.

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The eighth section of HUMBOLDT'S work commences by the following position: that it is essential, in galvanic experiments, that the nerve which is intended to excite contractions in a muscle, should be organically united with it. The heat of the exciting arcs, and the essays of Dr. WELLS on their friction, are next considered.

To develope all the circumstances in which the galvanic phenomena are successfully produced, it is necessary to consider the medium in which the chain, formed by the metals and living organs, is stationed. Whether the phenomena are the same in the different kinds of fluids; in those which are susceptible of forming drops, and in the gaseous fluids; together with the effect produced on them in rarefied air, and in condensed air; are questions relative to which HUMBOLDT deemed it important to make a series of experiments with a pneumatic apparatus. He directed his trials to seven kinds of gases, *in vacuo,* in condensed air, and in liquids, presenting afterwards the galvanic phenomena he had observed in plants. He had already confirmed the existence of the irritable fibre in the vegetable kingdom, by the experiments he describes in his chemical physiology of plants. These experiments had thrown a new light on the origin, mixture, nutrition, incitability, and irritability of the

the vegetable fibre, and had afforded the strongest evidence of its analogy with the animal fibre.

If vegetables are, however, provided with nerves, and if, in their instance, the sensible fibres are united to the irritable fibres, where are they to be sought? Undoubtedly in the membranes of the vessels. It is true, that the course of them can scarcely be distinguished, with the help even of the best microscopes; and that, instead of separate vessels, bundles of vessels can alone be perceived. The density of the tissue of the plants opposes another obstacle; and furnishes an additional reason why metallic irritation should possess but little efficacy in experimenting on plants.

To what particular phenomenon ought to be ascribed the effect of galvanism on the gramineous tribe, or on a cabbage plant, if it be not owing to the accelerated contraction of the coats of the vessels; to the more rapid circulation of the juices, and to the augmented secretions? Now, how can these effects be perceived in a substance deprived of a vital organization, so far at least as not to be evident to our senses? These difficulties, and others of an equally powerful nature, determined our naturalist to abandon the wide field of conjectures and hypotheses, and to institute a series of real observations, by galvanic experiments on small worms, leeches, earth

earth worms, and on the different species of cuttle fishes. The galvanic phenomena were manifested on the most minute aquatic worms. The presence of the sensible fibre was very noticeable in the *naiads*, a description of worms which, by their faculty of reproduction, surpass all the known kinds of *lumbrici* and leeches. Experiments were also made by HUMBOLDT on the *lernæ*, or water serpents; on the *tœnia*, and on the different species of ascarides, in the case of which the movements were, by the means of the oxygenated muriatic acid, accelerated for several minutes. This was, however, at the expence of their life.

As it results from the most precise observations, that the galvanic irritation acts on the nerves alone, the very insufficient knowledge which had been acquired relatively to the nerves of insects*, determined HUMBOLDT to institute, during three years, researches on their sensible fibres. Several considerations, he observes, lead him to think that the great irritability which is noticed in insects, is combined with a propor-

* It would appear from what HALLER observes in his *Primæ Lineæ Physiologicæ*, that he denies the existence of nerves in several insects, and in the tribe of *polypi*. The work of LYONNET does not point out a single vein in the caterpillar.

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tionate nervous energy. In support of this idea, he cites the effects of alcohol and electricity, which have been found by FONTANA to act on the sensible fibre alone. He was not enabled to trace the nerves with so much precision, in any other insect, as in the *cerambyx cerdo*. The most considerable of these nerves, distributed in the hinder extremities, are larger than horse hairs.

After having given an account of his galvanic experiments on insects, HUMBOLDT enters into a detail of those he made on fishes, the nervous organization of which is truly admirable. Accordingly, on dissecting them, he was convinced *a priori*, that this class of animals is extremely well adapted to galvanic experiments. "I have seen (he observes) fishes, the head of which had been cut off half an hour before, strike with their galvanized tail in so forcible a manner, that the whole of the body was raised considerably above the table on which they were placed." When their incitability was exalted by alkaline solutions, or by the oxygenated muriatic acid, the struggles of the fishes, more particularly of the eels and tenches, were such, that it was scarcely possible to master them. The slightest contact of metallic substances made them spring to a considerable distance.

In commencing the ninth section, HUMBOLDT observes that, in the class of amphibious animals,

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the phenomena of galvanism have been most frequently discovered and investigated. Frogs, which may be every where procured in great numbers; which are possessed of an almost indestructible irritation; the flesh of the muscles of which is in the nicest state; and the body of which is nearly transparent; have, unfortunately for them, attracted the particular notice of physiologists. The use to which NOLLET, in the first instance, and, afterwards, ROSEL, HALLER, and SPALLANZANI, applied frogs in their experiments, was but a feeble precursor of the fate which awaited them at the close of the eighteenth century, in every part of Europe, and in North America.

HUMBOLDT now enters into an explanation of the causes why the winter slumber of amphibious animals* augments their irritability. He brings forward the proof that the exercise of the intellectual faculties debilitates both the muscular fibres and the secretory vessels. He next proceeds to a variety of physiological observations on frogs, lizards, toads, and tortoises. The latter,

* The example of the longest sleep, or, rather, of the longest apparent suspension of life, is that of the *vorticella rotatoria*, which was revived by FONTANA, in the space of two hours, by moistening it with a few drops of water, after having kept it, motionless, and in a desiccated state, for the space of two years and a half.—See his valuable treatise on poisons.

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more particularly those found in the rivers, possess an irritability which continues for a very considerable time. P. MICHAËLIS excited very powerful muscular contractions in a tortoise which had been dissected and exposed, its heart having been taken out, for the space of eighteen hours, to the vigorous cold of the winter season. HEREMBSTADS found the muscular flesh of the common tortoise, *testudo europœa*, to be acted on by metallic irritation, at the time when the putrefactive process had commenced.

The galvanic experiments on man are unquestionably the most important. HUMBOLDT draws the attention of his readers to several observations which he had either passed over in silence, or had but slightly touched on, such as the luminous appearance which may be produced in four different ways. The discovery and publicity of this phenomenon, were, as has been already noticed, due to Mr. G. HUNTER, of York. HUMBOLDT explains by what conjunctions of the nerves galvanism at this time affects the visual organ, and inquires into the nature of the sympathy which subsists in an inverted ratio, between the olfactory nerve and the superior maxillary nerve. He observes that he was never able to remark, any more than PFAFF, either the contractions or dilatations of the pupil; and adds, that the contradictory results of the experiments made by

 FOWLER,

FOWLER, may be explained by those nervous sympathies; from which it results, that a strong light, in acting on the organ of sight, excites sneezing, and that ammoniac, in stimulating the organ of smell, produces the dilatation of the pupil. There had not, at the above time, been any instance of the galvanic action similar to that of the flash of light. Dr. MONRO was so excitable by galvanism, that he had a hemorrhage from the nose, when, after a very gentle introduction of zinc into the nostrils, he brought the above metal into contact with a coating applied to his tongue; and this bleeding constantly ensued the instant the flashes of light were perceived. This phenomenon, which is highly instructive to the physiologist, demonstrates how it is that the nerves by which the small blood vessels are surrounded, irritate and augment their contractions. It also confirms what anatomists have observed relatively to the influence of a sense of shame, as well as of joy, on the nerve of the fifth pair, and more especially those of the face.

HUMBOLDT apprehends that this violent irritation may be of great utility in certain pathological cases. Having supported this idea by facts which seem to argue in its favour, he proposes and points out the means of employing galvanism in the case of patients whose sight is conjectured to have been irretrievably lost.

In speaking of VOLTA's experiments on the tongue, he observes, that some idea of them had been given thirty years before, in SULTZER's work entitled "the New Theory of Pleasures," published in 1767; and that if, at the above time, the consideration of the superficial situation of the nerves of the tongue, had led to the artificial discovery of a nerve, the great discovery of metallic irritation would have been made in the time of HALLER, FRANKLIN, TREMBLEY, CAMPER, and BUFFON. How great a progress would not this discovery have made, if the above philosophers had transmitted to us, thirty years ago, the theory and experiments which we leave to our successors?

VOLTA having pointed out the differences, in point of savour, which result from galvanic experiments on the tongue, according to the nature and disposition of the coatings, HUMBOLDT repeated these experiments, and added to them several of his own, with a nearly similar result. His different trials, however, having failed to produce any contraction of the tongue, appear to have established the truth of the ancient assertion of GALEN, recently confirmed by SCARPA, namely, that the nerve with which the tongue is supplied by the third branch of the fifth pair, is exclusively devoted to the sense of tasting, and that the ninth pair are exclusively destined for the

the motion of the tongue. This has been evidently proved by the galvanic experiments on the nerve in question.

The termination, in the pituitous membrane, of the nerves belonging to the organ of smelling, which originate in the first pair, and in the first two branches of the fifth; together with the observation of the innumerable phenomena of sympathy between the organs of sight and those of smelling and tasting; had led to a presumption that, by galvanizing the nostrils, the smell would be affected. This supposition has not, however, been confirmed by any experiment.

Robinson and Hecker having published contradictory observations relative to the irritation produced in the sockets of the teeth, Humboldt has adopted those of the former of these physiologists. In the case of a wound of the hand, he saw an inflammation produced by the application of the irritating metallic substances; and this fact was afterwards corroborated by a trial he made on himself. Having abraded the skin of the wrist, with the effusion of a small quantity of blood, at the part where the radial artery is extremely superficial, he laid on the wound a coating of zinc, which he touched with a silver coin. As long as the contact continued, he felt a tenseness which extended to the end of his fingers, together with a shooting and tremulous sensation

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in the whole extent of the palm of the hand. This painful sensation became manifestly more intense, whenever the edge of the coin was brought in contact with the zinc; and the irritation likewise augmented the discharge of blood. As soon as this substance became clotted, the coating produced a much weaker effect. HUMBOLDT now took a scalpel, and, having made slight incisions in the part, the galvanic process, which he continued for several days successively, produced a very decided inflammation.

Two vesicatories, each of them of the size of a crown-piece, which he caused to be applied to his shoulders, and which were laid over the *trapezius* and *deltoides* muscles, were, after the vesicles had been opened, subjected to a similar experiment, the result of which was a fresh discharge of serosity, accompanied by a change of colour, a very acute pain, redness, and inflammation. He again repeated on himself this experiment, which was followed by the same phenomena. "This, he observes, demonstrates the organization of our machine, in the most astonishing point of view." The sensation which galvanism excited in him, did not appear to him to have the smallest resemblance with that which is occasioned by the electric fluid. It appeared to him to be a pain of a very particular and distinct nature.

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The reader will recollect that there was some mention of similar experiments, in the analysis of the seventh section of HUMBOLDT's work. He made them with a view to ascertain whether the muscular movements and sensations produced by galvanism, are prolonged after the chain has been closed. This induced him to apply two blisters to his back. We are informed, in BRUGNATELLI's medical commentaries, that Dr. CORRADORI tried an experiment of this nature on a woman labouring under an ophthalmic complaint. The sensation was similar to that which HUMBOLDT mentions; but the serosity, which was merely more abundant, had not acquired an additional acrimony. An individual aged fifty years can scarcely endure the pain which this experiment occasions; notwithstanding which, it was made on two aged females, without, however, presenting any particular result. It follows from what has been observed, that Dr. CORRADORI agrees with HUMBOLDT so far as the sensation is concerned; but differs from him respecting the increase and augmentation of the serosity. With respect to the effects of the galvanic irritation, the above physiologists concur in the opinion, that they have not the most distant resemblance to those of the electric shock. To prove this, several patients were, without their being sensible of it, electrified both by HUMBOLDT and Dr.

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CORRADORI; but without either of these physiologists being able to form any comparison between the effects, which were altogether different.

The greater the number of the nerves over which the galvanic fluid passes, the more evident are the effects of the irritation it produces. ACHARD, of Berlin, whose sagacity in experimenting is well known, was the first to establish a communication between the mouth and the anus, by the means of zinc and silver. In this way he excited pains in the bowels, augmented the energy of the stomach, and brought about a change in the evacuations of the intestinal canal. HUMBOLDT being persuaded that, in this experiment, all the nerves of the trunk are excited, conceived the idea of trying whether so active an irritation might not bring to life very irritable small animals, when they fall into a state which resembles death. He made choice of birds for his experiments. He watched the moment when a linnet was about to expire. The eyes being closed, and the little animal extended on its back, the point of a pin was thrust in near the anus; but the metallic irritation did not produce any sensible effect. HUMBOLDT now introduced a small piece of zinc into the bill, and a small bit of silver into the rectum, establishing an immediate communication between these metallic substances by the means of a portion of iron wire.

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"What was my surprize, he exclaims, when I perceived, the moment the contact took place, the linnet open its eyes, stand erect on its feet, and flutter its wings. It again breathed during six or eight minutes, and then expired tranquilly."

This experiment HUMBOLDT repeated successfully on two canary birds; and has no doubt but that it supplies a mode of bringing to life small birds reared in apartments; and which are sometimes drowned in the water given to them for the purpose of their bathing themselves. "Might not physiology, he observes, be made to pay, in this manner, a part of the debt it has contracted with animated nature, by the innumerable massacres it has occasioned?"

HUMBOLDT gives an account of a very interesting observation made by Dr. GRAPENGIESSER, of Berlin, relatively to the influence of nervous irritation on the peristaltic movements of the intestinal canal. The following are the most interesting particulars, as they were related by the Doctor himself.

A patient in the military hospital of Berlin, had been afflicted for several years by a very large scrotal hernia, which having accidentally become strangulated, formed an abscess, followed by a considerable suppuration, with an opening of the integuments, and a protrusion of a part of

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the large intestines, that is, of the cœcum, of the transverse arch of the colon, and of a part of the rectum, which were reversed in such a way as that their internal surface was become the external one. When the patient was seated, the ileum flowed out with the colon; and each of these intestines hung down to the knee. There were two openings, one on each side, which gave issue, the one to the injections administered to the patient, and the other to the excrements of ill-digested aliments. Between the colon and the small intestine, a large hard ring was perceptible, which formed a nice separation between them, and by which a strangulation was brought about in all the parts it comprised. The author of these observations conjectures it to have been the valve opening into the colon, which had been powerfully distended by the reversed state of the intestines, and which, in the course of the seven years the disease had subsisted, had lost its original configuration.

As soon as he had examined his patient, Dr. GRAPENGIESSER came to a resolution to subject him to a series of galvanic experiments, to which he submitted without the smallest hesitation. The Doctor accordingly armed a portion of the intestines with silver, and the other portion with zinc. Scarcely had a contact been established between the two coatings, when the peristaltic move-

movement became greatly accelerated, the undulations succeeding each other with an extraordinary rapidity. The patient felt an acute pain of a peculiar kind in the parts the metals touched. The galvanic fluid appeared to augment the action of the mucous glands, as well as that of the exhalent vessels, and likewise to render their secretions more abundant, in the same way as it had augmented, in the case of the wounds, the secretion of the serosity, after the application of the vesicatories which HUMBOLDT made on his back. Several large drops of fluid matter flowed in a few minutes from the intestines on the metals.

Dr. GRAPENGIESSER having in his recollection the experiments relative to the effects of alkalis on the nerves, slightly moistened the surface of the small intestine with the carbonate of potash in a deliquescent state; the consequence of which was, that the vermicular motion of the intestines became at least six times more powerful than before, although one application only of a coating was made. The patient, at the same time, felt an increase of pain.

The above experiments are on many accounts instructive. It appears by them, that the intestines, the vermicular motion of which is, in the opinion of physiologists in general, involuntary, are susceptible of metallic irritation. It follows from

from hence, that the Italian naturalists had made an erroneous decision, when they advanced that galvanism acts alone on the muscles dependent on the will. The latter of these experiments also demonstrates, that the peristaltic movement of the intestines is solely caused by the irritation of the nerves, seeing that it is impossible to irritate the intestinal canal, without irritating also the nervous filaments distributed in the cellular membrane; at the same time that the galvanic stimulus does not act unless the sensible fibre be coated, as was proved by HUMBOLDT at the commencement of his sixth section.

SCHMUCH, who made his experiments five months before FOWLER, was the first to observe the incitability of the heart, when acted on by the galvanic fluid. The latter, however, had an equal claim to originality, when he contrived to change the pulsations of the heart, without an immediate application of the coatings to that viscus, by the simple application of them, in experiments made on warm blooded animals, to the recurrent nerves of the *par vagum*, or eighth pair. PFAFF, LUDWIG, CREVE, and WEBSTER, confirmed the fidelity of the observations of PFAFF, when they repeated his experiments on frogs. As, however, in several of these experiments, the muscular fibre had been touched by the metals, a suspicion was entertained of the existence

existence of a metallic irritation. It therefore became important to enter on new inquiries relative to this fact. The silence of SCARPA, on the influence of galvanism on the nerves of the heart, was an additional reason why the experiments should be repeated.

HUMBOLDT engaged, accordingly, in a series of experiments on this subject; and, to avoid being led into error, made them in the presence of several celebrated physiologists, who paid a minute and particular attention to all the circumstances. He details the results at the close of his ninth section, in the analysis of which we are engaged.

He assures his readers that his experiments on the heart of frogs, lizards, and toads, were, in almost every instance, successful. Those which he made on the heart of fishes, demonstrated to him, that if, in their case, the viscus is the most incitable on the application of the oxygenated muriatic acid, it is also the most excitable by the means of metallic irritation. In Poland he dissected the fishes of the Vistula, which were excitable to such a degree, that not only iron and silver, but even copper and lead, sufficed to operate changes in the pulsations of the heart.

These experiments leave no doubt in the mind of HUMBOLDT, but that metallic irritation acts both on the muscles dependent on the will, and

on

on those which are independent of it, notwithstanding it may, in the instance of the latter, have a less powerful influence. As he has proved, in another place, that the galvanic phenomena are produced by the means of the sensible fibres alone, so, likewise, do the experiments immediately before us prove this very important fact; that the contractions of the heart are modified by the nervous influence. Relatively to the question, whether, in a galvanized heart, the irritation is invariably the same, whatever may be the point of that viscus to which the portions of muscular flesh, forming a part of the conductor, are applied, he replies affirmatively, observing that this arises from the multiplied distribution of the nervous filaments in every part of its substance. This multiplicity of nervous filaments had been proved by the descriptions of Andersch, by the great anatomical work of Soemmering, and, more particularly, by the plates which Scarpa has given of the cardiac and glosso-pharyngian nerves.

The reader must have observed that the preceding sections have been dedicated to the exposition of the galvanic phenomena in their fullest extent. In the tenth and last section, Humboldt considers these phenomena so far as they relate to the other powers of Nature. He sets out by an inquiry into the causes of galvanism, and proceeds from these to an investigation of

its theory. His first hypothesis necessarily regards the theory established by GALVANI.

In the first section of HUMBOLDT's work, mention was made of the great number of objections to which this theory had given rise, and of the very satisfactory manner in which it was refuted by PFAFF. The majority of the experiments made by M. HUMBOLDT himself, have also tended to demonstrate its insufficiency. By abandoning, however, the theory of galvanism, founded on the analogy of its phenomena with those of the Leyden phials;—a theory which has as feeble a basis as the calculations of SAUVAGES on the celerity of the animal spirits, the name of GALVANI will not suffer. It will be immortalized; and future ages, in availing themselves of the advantages of his discovery, will acknowledge that physiology owes to HARVEY and GALVANI its two principal and fundamental supports.

Our author takes no notice whatever of the theory of VALLI, on account of its being analogous to the preceding one, and because it is involved in so many perplexities, as to be refuted by each of the experiments on metallic irritation. That of VOLTA, founded on the destruction of the electrical equilibrium, is the most plausible of all those by which an explanation of galvanism has been attempted, and is, at the same time, the one which comprehends the greatest number of facts.

facts. It is explained by HUMBOLDT in all its genuine simplicity; but the experiments made by the latter, oblige him to declare himself the adversary of VOLTA. In his refutation he employs all the circumspection due to a man whose inventive genius, spirit of observation, and great address in experimenting, have been long known.

The opinion of the physiologist in question, was, in the first instance, that metallic irritation is, according to every probability, to be entirely ascribed to an unequal distribution of the electric fluid. Having, however, afterwards observed that several of the facts he met with in his experiments, could not be ascribed to external electricity, he became persuaded of the existence of a particular fluid, hitherto unknown, accumulated in the sensible fibre; and this fluid he denominated animal electricity. The complete exposition of his theory will be seen hereafter, in our analysis of his Letter to Sir JOSEPH BANKS. Notwithstanding it is founded, as has already been observed, on the destruction of electrical equilibrium; and although it may be applicable to a great number of new discoveries; this theory appears to HUMBOLDT to have been completely overturned by several of his experiments, as well as by the facts he cites, with which it is in manifest contradiction.

When our naturalist himself engages in the

task of hazarding an explanation of metallic irritation, and of its different effects on the muscular fibres, he does not undertake to refer to one and the same principle, all the galvanic phenomena, the degrees of the complication of which are so different; or to substitute another doctrine to that of the electrical equilibrium. He confines himself to a comparison of the facts; and, while he calls the attention of his readers to the relations they have with each other, he points out the probable mode of coming at a more precise and extensive knowledge of the subject he discusses. To communicate a thorough knowledge of the theory of HUMBOLDT, it would be necessary in this place to copy all the principles he lays down, as well as all the results of the experiments he made, and the general details into which he enters. As the plan we have laid down does not admit of so dilated an account, we must refer such of our readers as are desirous of this very particular information, to the work itself, and shall confine ourselves to an exposition of a few of the principles and results, by which his doctrine is sufficiently well established, to afford a clear and distinct knowledge of it. These principles and results we shall divide under eight different heads.

1st, As the organs are enabled to manifest, solely, and by themselves, the phenomena of galvanism,

galvanism, it is evident that they contain the stimulating cause.

2dly, Our author points out the necessary conditions to enable the metallic irritation to preserve its efficacy in the different degrees of the diminution of irritability.

3dly, He gives his theory, which is founded on the existence of a particular fluid, residing in the organs, and on its accumulation, occasioned by the obstacles with which it meets.

4thly, He attempts to explain all the phenomena, which he establishes on a small number of simple principles.

5thly, He explains the differences and relations between the galvanic, electric, and magnetic fluids.

6thly, He describes the particular effects of oxygen and zinc.

7thly, He treats of the active atmosphere of living organs, and of the hypotheses which relate to it.

8thly, and lastly, He expresses his doubt relatively to the explanation of galvanism given by Creve, who flattered himself that he had discovered the nature of galvanic irritation, and pretended that, by the means of two metals, or by the means of one metal and a piece of charcoal, the water by which the nerve and the muscle are surrounded is partly discomposed; and that the

oxygen, being attracted by the carbonated matter, is separated from the hydrogen. He adds, that this decomposition does not take place in the first instance, unless in the portion of water which is in immediate contact with the metallic, or other substances, but that it afterwards extends beyond that point. Chemistry, physiology, and practical medicine, ought, according to CREVE, to derive very great advantages from this discovery, on the nature of metallic irritation. He even hopes that its influence will be extended to the different branches of mathematics and natural philosophy.

In the above analysis of the very learned and philosophical work of HUMBOLDT, the long series of experiments it contains have not been given, because, in the first place, they are at this time generally known; and, secondly, because the majority of them could not have been comprehended, without the plates which are given at the end of the work. It will therefore suffice to state generally, what they all contribute to prove, namely, *that an animal, a part of which is brought in contact with a metallic substance, which may be denominated its coating, manifests, several hours even after its death, powerful contractions, when the coating, on the one hand, and, on the other, the adjacent muscles, are touched with the two extremities of another metal.*

It

It may not be improper in this place to give a short account of the discovery of CREVE on metallic irritation, referred to above. The most important circumstance, and the one which has been long considered as being absolutely essential to the successful issue of galvanic experiments, is that there should be, in the circuit or battery, two metals differing in their nature. It has already been noticed, however, that it has been proved, by experiments posterior to those of CREVE, that the effects of the galvanic influence are not confined exclusively to the cases of the application of metallic substances. We shall now see how they act, according to the theory of the above physiologist, and what are the effects produced by metallic irritation.

Several of the naturalists who have written on the subject of galvanism, have granted too much to the vital forces, while their influence has not been duly appreciated by others. According to CREVE, the irritant discovered by GALVANI belongs to the class of chemical irritants. He explains the phenomena of galvanism in the following manner:

"When a communication is established between two metals, or between a single metal and charcoal, the water by which the muscles or the nerve is surrounded, is partly decomposed. The oxygen, one of its elements, having a greater

affinity with the charcoal, or with the metal, than with the hydrogen, quits the latter. The decomposition merely takes place in the quantity of water immediately in contact with the metals; but the sphere of the influence of this decomposition has a less limited extent, as is proved by the following experiment. If you place a metallic apparatus in a glass filled with water, and if you afterwards introduce your tongue into this liquid, at the distance of nearly an inch from the metals, you will be sensible of the acrid and astringent impression which is characteristic of metallic irritation. The tongue is affected because it is placed in the sphere of the action of the decomposed water; and the nearer it is brought to the part where the metals communicate with each other, the greater is the intensity the sensation acquires."

However HUMBOLDT may have expressed his doubts relatively to exactitude of this theoretical explanation, the above appearances seem to point out the mode in which natural history and medicine may be improved by the help of chemistry. In the sciences, CREVE very justly observes, every thing is affected at the same time; and the analysis of water and air, may, as well as that of the ideas, have an inestimable influence on each of the physical and natural acquirements. This important truth acquires a new degree of evi-

dence

dence from the researches and favourable presentiments of M. CREVE. More precise ideas relative to the disengagement of hydrogen, and to the effect its passage through the atmosphere may have on animated bodies; a more perfect knowledge of the nature of the oxydation of metals in the bowels of the earth; more certain data relative to the phenomena of galvanism; and, perhaps, the discovery of a new branch of curative means, by a recourse to metallic irritants;—such are several of the corollaries to be drawn from his observations. We will now follow another physiologist, FABRONI, in several of his details on the reciprocal chemical action of different metallic substances, and on the explanation of several galvanic phenomena.

It has been seen, in several parts of this work, that various authors have comprehended, among the phenomena of galvanism, the one which SULTZER mentions in his Theory of Pleasures, that is, the sensation which is manifested on the tongue, as soon as a mutual contact is established between two metals, which would not have excited any sensation, if they had been separately applied to that organ. FABRONI expresses his persuasion that the identical agent which, in the above case, produces an unexpected savour, may likewise be productive of spasmodic contractions of the animal fibre, as soon as it is brought in contact,

contact, at one and the same time, with the sensible parts, and irritable parts, each of them laid bare. Far, however, from agreeing with the other physiologists, in ascribing these effects to an almost unknown agent, such as the electric fluid, he conceived, in the first instance, that they merely depended on a chemical operation. So early as 1792, he made several experiments on this subject; and communicated them to the Academy of Sciences of Florence.

Various facts which he observed at different times, convinced him that metals have a reciprocal action on each other; and that the phenomena which are displayed at the time of their union, or contact, are to be ascribed to this action. He was also satisfied by other facts, that metals, in the exercise of their power of reciprocal attraction, must diminish, in the same proportion, the force of respective aggregation; and that, although neither of them can, separately, attract the oxygen of the atmosphere, or deprive water of that principle, they acquire the power to do so by their simple mechanical contact, in consequence of the new combinations which take place. There is, therefore, according to his doctrine, reason to suspect that several, if not all the effects produced on the animal body by the metallic coatings, applied to the nerves and muscles, are ascribable to a chemical operation, namely,

namely, to the passage of the oxygen from any given combination to a new one, and to the development of the soluble, or sapid principle so sensibly manifested in the organ of taste.

Fabroni does not, however, undertake to exclude, in the principal facts which result from galvanism, every possibility of electrical influence. His aim is principally to prove, that this principle has no connexion whatever with the phenomenon observed by Sultzer; and likewise that several other analogous facts are drawn from the same source. In repeating the experiment made by the latter physiologist, he remarked that, when he wiped his tongue with all possible care, the sensation which is produced by the immediate contact of the two metallic substances, was diminished to such a degree as to be scarcely distinguishable. He concluded from hence, that the saliva, the lymph, or a humidity of some kind, has an influence on the phenomenon in question; and that, according to every probability, it is this humidity which, either totally or in part, forms a sapid combination with the metal, the aggregation of which is weakened by the contact of another metal with which it has an affinity. By the experiments he made on this subject, with metals plunged in water, he was convinced that a chemical action had taken place; and that it was unnecessary to seek elsewhere the nature

nature of the new stimulus, which, in SULTZER's experiment, had been called galvanism. He considered that it was manifestly owing to a slow combustion and oxydation of the metal; which combustion must have been accompanied by an attraction of oxygen, and by a disengagement of light and caloric. That the light is set free, is fully proved by a very ingenious experiment which FABRONI describes.

Being persuaded that the sensation of savour, and the emanation of light, in SULTZER's experiment, are, as has been before observed, merely the result of a chemical operation, he endeavours to disprove the physical arguments brought forward by those who, to justify their hypothesis, ascribe the above phenomena entirely to electricity. One of his proofs is drawn from the duration of the operation, electricity invariably acting in an instantaneous manner, and, on the other hand, the effects of chemical affinities lasting as long as there are any non-saturated re-actives left. If, among other proofs, he observes, it were necessary to demonstrate that electricity is totally unconnected with the phenomena in question, the experiments might be varied in such a way as not to prevent the effects of the electric fluid, and to be certain at the same time, by the evidence of the sight, that the combustion which takes place depends on the disposition of the metals,

metals, and on their chemical affinity. The processes he points out for this purpose, and the effects which result from them, seem to be unanswerable. "It is very clearly seen," he observes, in concluding, "by the results I have obtained from the simple contact of two metals, that is, by the oxyde and saline crystals, that a chemical operation is brought about, to which the sensations produced on the tongue and on the eye are ascribable. It is therefore highly probable, that the mysterious stimulus, which produces the convulsive movements of the animal fibre, in a great part at least of the galvanic phenomena, is owing either to these new compounds, or to their elements."

The following letter of the celebrated VASSALLI-EANDI, relative to the phenomena of the torpedo, which are very analogous to the effects of galvanism on animals, is inserted here, because it tends to confirm the theory of HUMBOLDT, described in the early part of the present chapter.

"I have perused HUMBOLDT's work on galvanism, which appears to me to be the most complete that has hitherto appeared*. I was well pleased to find that he agrees with me in opinion, that no certain conclusion has as yet

* This letter was written at the commencement of July 1799.

been

been drawn relatively to the nature of the galvanic fluid. He expresses, at the same time, his doubts on that of the phenomena of the electrical fishes, which he means to make the object of a future inquiry. I have no doubt but that his inventive genius will enrich this part of natural philosophy by the most interesting discoveries, at the same time that he will still continue to extend the boundaries of the other branches, in which he has so highly distinguished himself, by taking the most effectual route to come at the truth. In the mean time I shall point out my opinion, both as to what still remains to be done towards the discovery of the real cause of the phenomena of the torpedo, and the theory by which they may be explained. In the first place, I shall undertake to prove the veracity of the facts announced by REAMUR, HUNTER, WALSH, and several other physiologists. It even appears to me, that I have found some truths among the fabulous stories which ARISTOTLE, PLINY, and THEOPHRASTUS, have, as well as their commentators, published relatively to the torpedo. I shall endeavour to form a just appreciation of the singular relations which SCHILLING and KEMPFER have given on this subject. The observations of SPALLANZANI will, however, claim my most particular attention, seeing that they interest me more than those of any

any of the authors who have preceded him in this interesting inquiry; and because they have a great analogy to the theory of fishes possessing the faculty of giving electric shocks, as it was propounded by me in 1790 to the learned SENEBIER.

"May I therefore be permitted to advert to the above observations, before I proceed to the theory of the phenomena of the torpedo, which I am about to submit to the public. Being at Pavia in the year 1790, my friend SPALLANZANI, to whom I had before communicated my opinion relative to electric fishes, shewed me his large plates of the anatomy of the electric organs of the torpedo, and told me that, having cut the three great nervous trunks, which, in branching out, embrace the prisms, filled with soft matter, that compose the greater part of the body of the torpedo, he observed that the animal had lost the faculty of giving shocks. This led me to the observation that, in the case of the torpedo, the nerves express the electricity contained in the muscles; notwithstanding which, when the nerves have not been touched, the animal is capable of giving weak shocks, some time even after its death.

"The other observation made by SPALLANZANI is, that the fetusses of the torpedo are, in the belly of their mother, united to the egg by the

the umbilical cord; and that, in withdrawing them, they bestow slight shocks. He shewed me, in his museum, several of these torpedos attached to the eggs, observing that he had himself felt the shocks they gave under the above circumstances. The details of what had been observed relatively to the other fishes possessing the faculty of giving shocks, by MUSCHENBROEK, BAJON, VANDERLOT, FERMIN, &c. together with the anatomy of the torpedo and gymnotus electricus, by REDI, LORENZINI, BORELLI, HUNTER, REAMUR, &c. supplied me with the necessary observations to ascertain the true structure of these animals. On the facts contained in the above authors I have founded my theory, which I shall explain more fully hereafter, provided it should appear that its basis is established on true principles. It is briefly as follows:

" I suspect that the fishes which give shocks, possess the faculty of condensing the electric fluid in a given part of their body; and that, in the ordinary position of their internal organs, this fluid is retained by a non-conducting *veil*, which afterwards, either by the means of rarefaction, or by the addition of the humours, becomes a conductor, and admits the passage of the condensed electricity, as often as the fish is disposed to give a shock. According to this theory, the electricity is supplied by the air, and by the nourish-

nourishment, as in the case of other animals; and the electric organs constitute the part of the body in which the electric fluid is condensed. The medium in which the torpedo lives, does not oppose any obstacle to this theory, whether the structure of the animal be considered, or the nature of the watery element, so far as electricity is concerned.

"I shall not undertake to prove the former of these propositions, which possesses, notwithstanding, a very great degree of probability. It demonstrates that the different parts of the animal have, at one and the same time, contrary electricities; and the denomination of electric organs which has been given by various physiologists to the muscles described by Redi and Fermin, appears to me to confirm the second proposition. Be it observed that they did not bestow this name on the muscles of the fishes to which it refers, and which possess the faculty of giving shocks, until after they had been persuaded that the commotion which is received is electrical, and that it arises from the above organs.

"I might also strengthen my assertion by the nature itself of the organs of the torpedo, which are composed of a great number of hexagonal and pentagonal tubes. Hunter counted 1182 of these tubes in a muscle of a torpedo about a yard

in length, and they are, according to REAMUR, divided, each into several other small tubes, or cells, filled with a white and glutinous substance, which appears to be well calculated to retain the electricity. If we proceed to the examination of the structure of the *gymnotus electricus*, consisting in a great measure of a mucilage, which dissipates itself when rubbed between the fingers; and if we inspect the surface of its body, which is covered by small yellowish points, we find the latter to be the orifices of a similar number of small tubes, the majority of which are disposed on the head, and on the other parts that communicate the most powerful shocks. This structure agrees perfectly well with my opinion relative to the cause of the phenomenon.

"The effort made by the torpedo before it gives the shock, together with the contraction of its body, which, from being convex, becomes concave, and the depression of its eyes, which takes place at the same time, may tend to explain the modification of the non-conducting veil, and the escape of the electric fluid. Every one is well acquainted with the influence of our passions, and of our will, in modifying our internal organs; and it is besides known, that bodies lose their capacity to contain electricity, in proportion as their volume is diminished.

From

From hence should follow, in the torpedo, a greater condensation of the electricity, by the diminution of the volume of the animal, and a modification of the non-conducting veil, produced, at the same time, either by the will, or by the influence of the passions. Consequently the shock will be merely a result of the known laws of the electric fluid, and of the physical state of the animal. The diminution of the successive shocks, their frequent failure, and, lastly, their total discontinuance, are obedient to the same laws. The observation made by ABILGOARD, who, when at Naples, galvanized the torpedo, and who could not find in it any particular irritation, may be adduced in proof of the action of the will in the phenomena exhibited by that fish.

"The ideas I have just developed I am very far from giving as conclusive reasonings. It appears to me, however, that they possess a certain degree of probability; and it will be highly flattering to me if they should be found to contribute to the explanation of the phenomena of the torpedo, by supplying naturalists with new subjects, which may give rise to a number of interesting experiments and observations. If experiments, observes BACON, do not answer the expectation, they still inform the

the mind. Consequently the researches relative to a phenomenon which is still unexplained, cannot fail to be advantageous to the sciences."

To the facts contained in the above letter of VASSALLI-EANDI, it will not be amiss to add, that the experiments made by Mr. WALSH, to which he refers at the commencement, and which are to be found in the Philosophical Transactions for the year 1773, were repeated at Rochelle on a considerable number of torpedos, in the case of which the learned naturalist in question constantly felt the commotions, but without any manifestation of a spark. In 1776 he was enabled to make several experiments on the gymnotus electricus, or tremulous eel of Surinam, and not only felt the shock, but observed the electric spark. He also obtained the same result, in experimenting, in London, on five living fishes of this description. M. GUISART also made, at Cayenne, several experiments with two gun barrels, one of which was brought in contact with the head, the other with the tail of the fish, and perceived the electric spark. Thus, it has been fully proved that the phenomenon referred to is truly electrical. It had not, however, been extended to other animals, beside the electrical fishes, until the observation made by COTUGNO,

Cotugno, alluded to in the third page of this work, was published. This observation is the more interesting, as it gave rise to the experiments made by Galvani, which led to his important discovery.

CHAP. X.

Extract from a memoir by M. PFAFF, *relative to the experiments of* HUMBOLDT *described in the preceding chapter.—Memoir of* M. LEHOT, *on the circulation of a very active fluid in the galvanic chain, and on the direction of its motion.*

IT would appear that, in the case of experiments, the results should be the same to every man of science; and that, when they are repeated, what has been sensible to the touch and to the eye of the first experimenter, should be equally so to the second, the third, and so on. For, be it observed, it is not the same with the external as with the internal senses. Our mode of reasoning, our judgment, and our ideas, necessarily vary, according to the manner in which each individual views the object he examines, or according to his prejudices, and the first idea he has conceived of its explanation. But ought it to be the same, when the object is subjected to the external senses, to the sight and to the touch, and when the experiments present phenomena which

which are manifest to these senses? And why are not these phenomena invariably the same to each of the observers? Whatever the cause of this may be, it is certain that it occurs daily; and the galvanic experiments of M. HUMBOLDT, described in the preceding chapter, are an additional proof of the justness of the remark.

A little time after his work had appeared, M. PFAFF, the celebrated physiologist of Kiel, published a memoir on the experiments it contains, which engrossed much of the conversation of the scientific world. After having repeated HUMBOLDT'S experiments, he there asserts that he found results totally different from those which that naturalist had announced. He undertakes to prove that the chemical action of different bodies on the fibre, agreeably to the supposition of HUMBOLDT, does not exist; and that these bodies act merely because they form a part of the electric chain. He besides endeavours to demonstrate, that the different hypotheses laid down by HUMBOLDT, are in contradiction to each other; and that, after a perusal of his work, the reader has made no further advances than heretofore, in the knowledge of the physiology of organized bodies. He is persuaded that we ought rather to confess our ignorance relative to the unknown process of vitality, than to pay an attention to hypotheses so devoid of all proof and

demonstration as are those of HUMBOLDT. He is of opinion that a false application of chemistry to the physiology of the human body, occasions the retrogradation, rather than the progress of science.

"We give way, he observes, to an agreeable illusion, and, imagining our knowledge to be complete, we cease to investigate. Who would ever have imagined that two or three drops of alkali, or of the oxygenated muriatic acid, would be capable of producing a chemical change in a great number of muscles, all of which become convulsed on the application of these substances? HUMBOLDT supposes, in the first place, that the fixed alkalis act by the means of the azote and hydrogen which, according to him, they contain; and, secondly, that two oxydable bases, the azote and the hydrogen, advance the chemical process of vitality, while two other similar bases, contained in the carbonated hydrogen gas, namely, the hydrogen and the carbonate, retard that process. He assures us that two substances, so very different as fixed alkali and the oxygenated muriatic acid, act in the same manner, at the same time that the chemical affinities of these two substances are altogether opposite. No, no, he exclaims,—it is not by chemical affinities that life is to be explained!"

He attempts to prove, by a series of very ingenious

genious experiments, that water is, in this case, if not the sole agent, at least the principal one. He observes that, by employing a bit of spunge, moistened with water, the different effects detailed in HUMBOLDT's experiments may be produced; and expresses his persuasion that galvanism is nothing more than animal electricity, which has been long known, and latterly brought forward by GALVANI, HUMBOLDT, and others, to be again forgotten. It must be confessed that this is a very bold assertion.

"It cannot be questioned," says PFAFF, "but that vital chemistry, which appears to be the favourite object of the meditations of the physiologists of the present day, has been elucidated, as well as greatly extended in its limits, by HUMBOLDT's experiments on the excitability of the muscles and nerves. The indefatigable zeal employed by that writer, together with the sagacity and spirit of observation of which he has given so many conspicuous proofs, in a multitude of researches on physiology, must necessarily have led him to very interesting results. The inferences, however, which he draws from his experiments, as well as the explanation he gives of the phenomena he has observed, are not invariably fixed on a solid basis."

The very remarkable effects produced by chemical substances on the sensible and irritable fibre,

fibre, are, it would appear, susceptible of an explanation different from the one adopted by M. HUMBOLDT. It is for this reason that PFAFF proposes another, which he thinks more just, and, at the same time, more coincident with the different phenomena of galvanism. The following are his reasonings on this head, together with the experiments on which they are founded.

"A very important circumstance," he observes, "to which HUMBOLDT did not pay attention, in his experiments relative to the influence of chemical substances, as exciters of irritability, is the effect of them as members of the galvanic chain. Among these substances may be enumerated the different alkaline substances, acids in general, the oxygenated muriatic acid in particular, and liver of sulphur. I have examined them, in the above point of view, in a series of experiments, and have found several of them to be as efficacious links of the chain, and as powerful exciters of galvanism, as metallic substances themselves.

"The table published by M. HUMBOLDT, of the intermediate links of the chain of his boasted exciters and conductors of animal electricity, should be entirely altered, if it be intended to represent the scale of the conducting and exciting forces of these substances, in whatever relates to galvanism. Liver of sulphur, the alkaline solutions, lime-water, and the oxygenated muriatic

acid,

acid, ought to be ranked before all other substances, metals and charcoal excepted, and immediately after them. The blood also should be considered as possessing a great degree of energy. I have convinced myself, by repeated experiments, made attentively, and with the most scrupulous exactitude, that alkaline solutions, lime-water, the oxygenated muriatic acid, and, more particularly, liver of sulphur, produce, when brought into reciprocal action, effects equally powerful with those of two heterogeneous metals; and that, in all the cases in which the recurrence of the contractions is ascribed to an increase of irritability, produced by a chemical action, it would be much better to ascribe this effect to the irritating property of these substances, as they constitute a part of the galvanic chain.

"They form, in a manner, a series of metallic exciting arcs; and ought to be ranked among those which have the greatest affinity with metallic substances, that is, with zinc and lead. It is on this account that their effects are so noticeable, when they are combined with gold, silver, and metallic minerals. They are also very efficacious in the reproduction of the contractions, when, instead of being applied in an immediate way to the nerves, they are simply made to correspond with them by the means of conductors. The blood and the bile ought also to be comprehended

hended in the same class, although their effect may not be equally powerful.

"It is well known that it suffices, for the production of convulsive movements in a very irritable frog, to employ a homogeneous metal, for instance a silver *discharger*, by which a communication is formed between the muscles and the nerves. These convulsive movements are principally produced by the metals denominated *noble*; but, more especially, by metallic minerals, such as pyrites and galena, or sulphuric ore of lead. When I had formed a communication between the nerve and the prepared thigh of a frog, by the means of a bit of pyrites, the convulsions were produced, and were more particularly manifested when that substance touched the blood-vessels belonging to the nerves. When a chain was established in the thigh, and the mineral substance and nerve had ceased to produce any effect, the convulsions were re-produced, although feebly, by interposing in the chain a bit of moistened sponge, which formed, in a manner, a coating to the nerves. These effects were not usually, however, of any long duration. By moistening, afterwards, the nerve with a drop of blood taken from the frog subjected to the experiment, or, what amounts to the same thing, from any other, and afterwards touching the blood in question with a metallic exciter of silver

ver or copper, placed on the thigh, very powerful convulsions were instantly produced.

"Here the susceptibility of irritation was evidently augmented by the moistening of the nerve with the blood. It was even so to such a degree, that a galvanic irritation of the feeblest kind became very powerfully augmented. This augmentation of the contractions was not, however, to be ascribed to an immediate influence of the blood on the nerve, and on the irritability, seeing that the same phenomena were manifested, precisely in the same way, when the blood, instead of being immediately applied to the nerve, was simply laid on a bit of sponge, or on any other conducting body, placed over it. The success of the above experiments depended entirely on the immediate contact of the blood; since, whenever the nerve, or the sponge, was touched at the parts distant from it, the effect did not ensue. To the presence of the blood ought more particularly to be ascribed the properties of animal substances, considered as members of the galvanic chain.

"In this latter point of view, the heart of the frog, still replete with blood, displayed very singular effects, at a time when the irritability was extinguished to such a degree, that certain heterogeneous metals, such as gold and silver, or silver and copper, no longer produced any effect when brought in contact. I was enabled to reproduce

produce very forcible contractions, by placing the heart of a frog on its nerve, and by forming a communication between it and the thigh of the animal, by the means of a metallic exciting arc either of gold or silver. In this manner I established a galvanic chain, in the composition of which one metallic exciter only was to be found. In another instance, it was very remarkable, that the moment the heart was touched, either by silver or by pyrites, it remained tranquil, notwithstanding the thigh of the animal was in a convulsed state, the regularity of the system of the pulsations not being in any degree interrupted. Other parts of the frog, for instance, portions of its liver, its bowels, &c. which contain a less proportion of blood, did not possess an equal efficacy; but the heart itself was surpassed by the blood presented in substance, and more particularly in a concrete state. It was surprizing to see the mode in which I could, by the means of a drop of blood, bestow on the nerve its vital energy; and also to observe that this drop of blood, without undergoing any sensible diminution or change, still continued to render the same service.

" Whatever may be the effect, however, which the blood produces, it is still surpassed by the alkalis, by the oxygenated muriatic acid, and, more particularly, by the liver of sulphur, when

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metallic exciters of the first class, that is, the minerals and noble metals, together with the other metallic substances, and the regulus of antimony, cease to produce any effect, in conjunction with the blood with which the nerve has been moistened. After having wiped it dry, and substituted to the blood a single drop of the deliquescent oil of tartar, very powerful convulsive movements may be produced, by a recourse to the above metallic exciting substances. This galvanic chain, consisting of muscles, silver, pyrites, or regulus of antimony, and of an alkali and a nerve, is as efficacious as a chain formed by muscles, silver, iron, or tin, conjointly with a nerve. The deliquescent oil of tartar may be considered as an active coating of the nerve. These phenomena present themselves agreeably to the same identical laws by which the metallic coatings of the nerves are regulated. In the above process, the deliquescent oil of tartar possesses nearly the same activity, whether the nerve, without being moistened in an immediate way, is made to communicate with the muscles by the means of any conducting body whatever, or is immediately touched by the metallic exciter applied to the thigh of the animal, the exciter in question being a bent silver probe.

"The following experiment merits a particular notice. I laid a portion of muscular flesh on the

the nerve of a frog, in the case of which two heterogeneous metals, silver and copper, had ceased to produce any effect, and having touched the nerve with a silver probe which was applied to the thigh, was not enabled to produce any contractions. I now poured a drop of the deliquescent oil of tartar on the muscular flesh, and as soon as the silver probe was brought in contact with this alkaline substance, very strong convulsive movements were displayed. I laid another portion of muscular flesh on the preceding one, and brought the exciter towards it, but without being enabled to produce the contractions. Scarcely, however, had this latter portion of muscle been moistened and touched, as in the former instance, than they were renewed. In this way I was enabled to form several layers of a different nature; and the effect above pointed out took place as often as the silver, or, what was still better, the pyrites and the regulus of antimony, came in immediate contact with the alkali. The nerve having been moistened with the deliquescent oil of tartar, a very feeble galvanic irritation, produced either by gold and silver, or by silver and copper, became highly exalted, even when the convulsions had not been previously excited. It remains, however, to be ascertained, whether, in this case, the deliquescent oil of tartar did not act as the most efficacious coating of

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the nerve. It is in this way that silver and copper produce fresh contractions, when, after the nerve has been coated with zinc, and the thigh of the animal laid on silver, a communication is formed between them by the means of copper. In such a case, indeed, the effect is not owing to the joint operation of the copper and silver, but, on the other hand, to that of the silver and zinc, by which the humid animal parts are immediately coated. Would not an effect exactly similar be produced, if the nerve were to be moistened with the deliquescent oil of tartar? Does not this alkali, in surrounding the nerve, become a more efficacious coating than the zinc; and, on the application of feeble exciters, such as copper and silver, does not the zinc itself act more powerfully by the means of the alkali, with which it is simply connected by the copper, as an intermediate conductor?

"These doubts are very far from being removed by M. Humboldt's experiments. Supposing the deliquescent oil of tartar to act by producing an augmentation of irritability, this effect ought also to be produced when the nerve has been carefully dried, before the application of a weaker galvanic irritation is made. This, however, is what I have not found in any of my experiments. M. Humboldt constantly applied his weakest exciters, while the nerves were still moistened

moistened with the deliquescent oil of tartar, or with any other chemical substance calculated to augment the susceptibility of irritation. On this head, let the different parts of his work in which he treats of the increase of this susceptibility by the alkalis, be compared. He sets out by saying: *I shewed the galvanic flashes to several persons who could not perceive them in the experiment made by Mr.* G. HUNTER, *by rubbing their gums, on the upper jaw, with an alkaline solution. Two pieces of gold, applied to wounds on the back, were found to possess great efficacy, when the wounds had been touched with the deliquescent oil of tartar.* A little further he observes: *When the principal trunks of the nerves of an organ of movement are carefully prepared, and enveloped in moist bits of bladder, in such a way as that the irritating humidity simply moistens the muscular flesh, and the few fine nervous filaments it contains, an increase of irritability is rarely observed; at the same time that it is constantly produced, when the above principle trunks are moistened beneath the muscles.* Again, he says in the following page: *The vital principle will be restored in the thighs of frogs exhausted by galvanic experiments, by the means of the oxygenated muriatic acid, in such a way as that the irritation of metals will again produce its effect. It is remarkable, that the contractions become more powerful, when a*

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great portion of the nerves is moistened, and touched in a direct way by the silver. Such are the extracts I have chosen to cite from HUMBOLDT's work. Now, let it be observed that, in all the above cases, and more particularly in the experiments relative to the influence of chemical substances on the irritability of the animal fibre, the nerves were constantly moistened by these substances. They must consequently, whenever the metals were applied, operate likewise as links, or numbers, of the galvanic chain. The consequences must therefore be uncertain at the least.

" I could not observe any remarkable difference in the alkalis, considered as links of the galvanic chain. The deliquescent oil of tartar appeared, however, to be somewhat more efficacious than the other substances of this nature. The effects of lime-water were not so powerful: it appeared, as it were, to preserve a medium between the alkalis and the substances to which an inferior degree is assigned. The oxygenated muriatic acid appeared to me to be pretty nearly as active as the deliquescent oil of tartar. In a few cases only the latter fluid produced spasmodic contractions of a longer duration. I observed likewise, in several instances in which I employed the oxygenated muriatic acid, a phenomenon which the metallic coatings of the nerves had

often displayed, namely, that the contractions were manifested at no other time than when the contact of the nerve, moistened with a drop of the oxygenated muriatic acid, ceased. Here, likewise, the effects seem to depend entirely on the immediate presence and application of the oxygenated muriatic acid. As soon as a drop of this liquid is poured on a portion of muscular flesh, laid on the nerve, the movements are invariably reproduced."

Having entered into this detail of the objections of M. PFAFF to the theory of HUMBOLDT, we shall proceed to the analysis of a very curious memoir, read by M. LEHOT at the French National Institute. Its object is to demonstrate particularly, not only the circulation of a very subtile fluid in the galvanic chain, but likewise that, in the application of the different chains to the animal arcs, there are unequivocal signs of the direction of the motion of that fluid, insomuch that it is possible to determine *a priori*, in a considerable number of different chains, the direction of the current. Being acquainted with this direction, as well as with the nature of the different parts of the chain, the author of the memoir in question observes, that it is reciprocally possible, in certain cases at least, to determine their respective position; and also, by the interposition of new substances in the chain, or

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by a change in the disposition of the parts of which it is composed, to give a particular direction to the galvanic fluid, and even to bring it into a state of repose.

The comprehension of these phenomena is connected with a fact which seems to have escaped the notice of the different physiologists, namely, that the galvanic fluid is accumulated in the passage from the organs to the coatings. By a due attention to this fact, the nature of the metallic substances may likewise be distinguished at the distance of several yards. The galvanic influence will be sufficient to determine this. The following are the principal results of the interesting experiments made by M. Lehot.

Experiment I. If the thigh of a frog recently prepared be held in one of the hands, and the nerve be brought in contact with a piece of zinc, the extremity of which is immersed in mercury, the moment the fingers of the other hand are dipped in that fluid, powerful contractions will be manifested in the thigh of the animal. The same result will be obtained as often as one of the following substances, namely, zinc, lead, tin, mercury, bismuth, copper, silver, or plumbago, be employed as a coating to the fingers; and one of those by which it is preceded in the foregoing

series, as a coating to the nerve. With respect to the precaution of moistening the fingers, it is absolutely indispensable, for which reason, whenever they are described as terminating one of the extremities of the arc, they are to be constantly supposed to be in a humid state.

Experiment II. If, on the other hand, the nerve be brought in contact with the mercury, and if that metal be touched with a piece of zinc, held in the moistened hand, either the contractions will not be produced, or they will be extremely feeble, provided there still be a certain share of susceptibility in the part. By separating, however, the nerve from the mercury, or, in general, by breaking the chain at any given point whatever, the contractile movements will take place. The same results will be obtained, as often as one of the metals belonging to the series pointed out in the preceding experiment, be employed as a coating to the fingers; and one of those by which it is followed in that series, as a coating to the nerve. Thus, if the nerve be coated with lead, and the fingers with zinc, there will not be any contraction when these two metals are brought in contact; but if the chain be destroyed at any given point, the contractions will be manifested. But if, on the other hand, the nerve being still coated with lead, the fingers

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be coated with silver, when the chain is formed, the galvanic contractions will take place*.

Experiment III. If a flat surface of zinc be laid on the tongue, and touched with a piece of silver, held between the moistened fingers, a particular savour will be instantly perceived. Much has been said on the subject of this phenomenon, but it has been no where noticed, that it likewise takes place whenever the tongue is coated with any one of the metallic substances pointed out in experiment the first, and the fingers with one of those by which it is followed in the series. If, however, after the chain has been formed, it be interrupted, the savour will be no longer manifest.

Experiment IV. If a piece of silver be laid on the tongue, and a portion of zinc be held between the moistened, fingers as soon as the latter is brought in contact with the silver, there

* These experiments, which succeed perfectly well with the mercury, without any particular precautions, require great circumspection in obtaining determinate results with the other metallic substances. It is not only necessary that the susceptibility should be weakened in a very great degree, and, that there should not be any communication between the coating of the nerve and the muscle, unless by the nerve itself; but it is likewise essential to prevent the kind of oscillatory movement which communicates itself to the parts of the chain, by the hand by which the contact is established,

will not be any distinguishable sensation, or, at the least, it will be very slight. As often, however, as the chain is interrupted in any given point whatever, the savour will be perceptible. It will not in this case be so strong as in the preceding experiment, and will be more slowly communicated.

The same result will be obtained, as often as one of the metals pointed out in the first experiment is employed as a coating to the tongue, and one of those by which it is preceded in the list, as a coating to the fingers. Thus, by coating the tongue with lead, and the fingers with zinc, and by bringing the two metals in contact, the savour will not ensue; but, by interrupting the chain at any given point, it will be very perceptible. On the contrary, if, the tongue, being still coated with the lead, the fingers be coated with silver, instead of zinc, and the chain established, the sensation will be instantly perceived.

Experiment V. If the thigh of a frog be laid on a plate of silver, and the nerve on a surface of zinc or lead, the moment the coatings are brought in contact, powerful contractions will be produced. The same thing will happen whenever the coating of the nerve is made to consist of a metal selected from among those which are pointed out in experiment the first; and that of the

the muscle, of another metal following it in the series.

Experiment VI. If the muscle be armed with zinc, and the nerve with silver, the contractions will not ensue until the moment the chain is interrupted. To the end, however, that the result of this experiment may be decisive, the precautions pointed out in the note to the second experiment, ought to be strictly adhered to. When portions of copper, iron, bismuth, and lead, are substituted to the silver, the same results are obtained.

In the first, third, and fifth of the preceding experiments, it must have been observed, that the phenomena were manifested the moment the galvanic circle was formed. The fluid contained in the parts of the chain was put in motion, and penetrated instantly either to the tongue or to the nerve. By reversing the chain, a contrary direction must have been given to the current, seeing that the phenomena which were manifested in the second, fourth, and sixth experiments, that is, those in which the galvanic influence was not perceptible until the instant when the chain was interrupted, were to be ascribed to a portion of the fluid, accumulated either in the tongue or in the nerves, at the points of contact of these organs with their coatings. Now, to the end that the

the fluid should have been thus accumulated, it was necessary that it should have penetrated the above organs in the direction of the muscle towards the nerves, or of the fingers towards the tongue. It is thus demonstrated, that the accumulation of the fluid is a sure characteristic of the direction of the current, by the help of which it may in all cases be determined.

In conformity to the experiments which have been detailed above, and to the galvanic facts already known and established, it would appear that the following principles may be laid down.

1st, That all exciting substances contain the galvanic fluid; but that its quantity is very inconsiderable in humid substances, and in the organs of animals, which have a very small capacity for that fluid, when compared with metallic substances.

2dly, That, when two exciting substances are brought together, a new distribution of the galvanic fluid takes place; the substance which has the least capacity losing a portion of the fluid, on which the other substance seizes. Metallic and carbonated substances, disposed in the following order—*zinc*, *lead*, *tin*, *mercury*, *bismuth*, *copper*, *silver*, and *plumbago*, act in such a manner as that any one of them, when brought in contact with one of those by which it is follow-

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ed, seizes on a portion of the fluid the latter contains.

3dly, When the galvanic fluid penetrates the tongue, in directing itself from its extremity towards its root, it causes in the latter part a particular savour, which is more or less strong, according to the greater or less quantity of the fluid, and to the susceptibility of the organ. But when its direction is such, that it tends to flow out of the animal arc by the tongue, it occasions a much weaker savour, which differs from the former in proportion as the quantity of the fluid, put in motion, is less. As the fluid, however, finds some difficulty in quitting the tongue, it partly accumulates in that organ; and when the cause which has given rise to this accumulation ceases, then the fluid, in returning towards the root of the tongue, occasions there the galvanic savour in question.

4thly, When the galvanic fluid, distributed by the nerves, penetrates into the muscular substance of the organs of living animals, recently separated from the animals themselves, contractions are produced in the parts it permeates. The susceptibility being exalted, if the fluid inherent in the organ, should, from any cause whatever, be unequally distributed, and accumulated at the particular points, muscular movements will ensue. But if the susceptibility is weakened, the

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contractions can no longer take place, unless by the aid of a fluid extraneous to the organ.

At the earliest stage of the diminution of the susceptibility of the organs, the contractions are displayed, whatever may be the direction of the fluid by which they are permeated. But when the susceptibility is weakened still more, the direction of the current ceases to be indifferent. When the fluid is directed in such a way as to pass from the nervous ramifications to the nerves themselves, the contractile movements are much weaker than when it receives a contrary direction; and in the former case a portion of the fluid becomes accumulated at the point where it has a tendency to flow out from the nerve. This accumulation, and this difference in the effect of the current, by which the organ is penetrated in one direction or in another, are greater in proportion as the susceptibility is less, and as the quantity of the fluid, put in motion, is smaller. Thus, when the susceptibility is greatly enfeebled, notwithstanding the contractions may ensue, when the fluid penetrates into the organs, in the direction leading from the nerve to the muscle, they cease altogether when it permeates them in a contrary direction, it being then almost completely accumulated in the organ. The cause which has given rise to this accumulation having ceased, the fluid returns into its

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accustomed channel, and, having penetrated the organs in the most favourable direction, occasions in them the muscular movements.

5thly, If a communication be established between two points of an animal organ, with the help of a chain composed of different substances, disposed in such a way as that it may not be symmetrical, relatively to the nature of the parts of which it is composed, the fluid being unequally solicited on the one hand and on the other, puts itself in motion, and forms a current directed towards the preponderating force.

6thly, If all the parts of the chain, by which a communication is established between two points of a system of organs either nervous or muscular, be reversed, a current will be produced having a contrary direction to the former.

7thly, When the chain is symmetrical, relatively to the nature of the parts of which it is composed, the fluid, being equally solicited on all sides, will forbear to display any movement.

8thly and lastly, When a chain which is calculated by its nature to give motion to the galvanic fluid, is destroyed, that is, when an insulating body is interposed, the fluid which had been accumulated in the organ by the formation of the chain, returns to its pristine situation, and a current is formed in a contrary direction to the first.

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These principles, which form the basis of the theory of galvanism, are likewise confirmed by the following experiments:

Experiment VII. If a thigh of a frog be held in one of the hands, and the nerve coated with zinc, at the same time that the person who makes the experiment has his tongue armed with silver, the thigh of the frog will contract as soon as the two metals are brought in contact; but the experimenter will not be sensible of any savour, or of a very slight one at the most. By interrupting, however, the chain, he will perceive a very distinct savour, and the thigh of the frog will cease to contract. If, on the other hand, he coats his tongue with zinc, and the nerve with silver, the savour will be manifested at the moment of the contact; and the thigh, provided its incitability has been weakened, will preserve a state of perfect immobility.

By the interruption of the chain, the muscular movements will be again apparent, without any manifestation of the savour. It will appear that this ought necessarily to happen, when it is considered that, as soon as the chain is formed, the current of the fluid takes a direction from the silver to the zinc, and having penetrated in a direct and immediate way into the nerve, produces contractions in the muscle, at the same time that it crosses the body of the person by whom

whom the experiment is made, and accumulates on his tongue, without his being sensible of any particular savour. When, however, the chain is interrupted, the accumulated fluid returns to the parts it had quitted, and the savour on the tongue becomes manifest. If the tongue be coated with zinc, and the nerve with silver, the current being impelled in a contrary direction, the phenomena which take place are diametrically opposite.

Experiment VIII. If two persons, holding each other by the hand, arm the tongue, one of them with zinc, and the other with silver, as soon as they bring the two metallic substances in contact, the one who has the tongue coated with zinc is sensible of the savour; but this does not happen to the other. If they afterwards separate the zinc from the silver, the one who felt the savour at the time when the chain was formed, will cease to be sensible of it on its being thus interrupted; at the same time that it will be rendered manifest on the tongue of the other.

Experiment IX. Finally, the animal arc may be terminated by two nerves. Thus, by placing the two thighs of a frog on a plate of glass, and establishing a communication between their muscles, by the help of a flat piece of metal, coating at the same time the nerve of one of them with

zinc, and the other with silver, the thigh which is armed with zinc, will contract the moment a communication is established between the two coatings, by the means of a rod of zinc or silver; the incitability of the other thigh having been weakened, the limb will remain motionless. By interrupting the chain, however, the muscular movements will be displayed in the latter, and the former will resume a state of repose.

Experiment X. The same disposition being made as in the second experiment, and the chain established, if a given point of the muscle be brought in contact with the mercury, without deranging the contact of the nerve; or if a communication be established between the muscle and the mercury, or between the musele and the zinc, by the means of a metallic substance, the muscular movements will be instantly manifested. These phenomena are occasioned by the fluid accumulated at the point of contact between the nerve and its coating, which fluid returns into the muscle, and there gives rise to the contractions. This is proved in the following manner: If, while the communicating metallic substance still touches the muscle and the mercury, or the muscle and the zinc, the latter be detached from the mercury, the contractions will not ensue, as would have happened if the fluid accumulated by the original chain, at the point of contact

tact of the nerve and its coating, had remained there.

Experiment XI. If the thigh of a frog, prepared in the customary manner, be held in one of the hands, and the nerves, as well as a few points of the muscle, be brought in contact with the mercury, the moment that fluid is touched by a bar of zinc, held in the other hand, previously moistened, violent contractions will be produced in the limb of the animal. This experiment consequently presents phenomena entirely different from those which were the result of the second experiment. The fluid, instead of having been accumulated in the nerve, appears to have flowed out by the muscle, and to have there occasioned the contractions. Such a degree of incitability may be induced, that the contractions may be altogether subdued by the double contact of the nerve and the muscle, as well in forming as in interrupting the chain.

Experiment XII. If, the same disposition having been made as in the sixth experiment, not only the nerve, but likewise the muscle, be made to touch the piece of silver, leaving it, however, in constant contact with the zinc, violent contractions will be manifested as soon as a communication is established between the zinc and silver, by the means of a conducting substance. By substituting to the silver, either copper, plum-

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bago, or lead, the same phenomena will be obtained.

The current which is formed in a chain composed of three metallic substances, is constantly directed towards the extreme metal stationed in front of the metal at the other extremity of the chain. The direction of the current cannot therefore depend, in any degree, on the metal by which the middle space is occupied.

In a chain composed of metallic and humid substances, where there are only two or three heterogeneous metals in immediate contact, the current is directed in the same way as it would be, if these metals were to be regarded as independent of the rest of the chain.

Effect of a chain composed of three substances of the first class, and one of the second class, followed by considerations on homogeneous metallic coatings. Having placed a thin plate of zinc at the bottom of a vessel filled with water, and brought the tongue in contact with the extremity of a bar of tin, the other extremity of which is made to touch the plate of zinc; if another bar of the same metal, of the same dimension with the preceding one, be held in one of the hands, and its extremity plunged in the water, there will not be any perceptible savour. In reality, the current is, in this instance, directed in such a way as to pass through the fingers,

fingers, crossing the body of the person by whom the experiment is made, to accumulate itself on the tongue. But as soon as the second bar of tin is plunged more deeply in the water, so as to touch the zinc, the savour becomes perceptible*. This phenomenon, which had not hitherto been noticed, is, according to M. LEHOT, a natural result of the principles he has laid down. By bringing, he observes, the second bar of tin in contact with the zinc, a symmetrical chain is formed, of such a nature, that the fluid it contains must necessarily be *in equilibrio*. Consequently, the quantity of the fluid which had been accumulated in the preceding disposition, must unavoidably have been dispersed, and have occasioned the sensation or savour which was noticed. On detaching the bar of tin from the plate of zinc, without taking it out of the water, the sensation ceases to be perceptible, on this account, that a current is formed which is directed in such a way as to penetrate the fingers. If the bar of tin be withdrawn from the water, the savour will

* If, instead of bringing the second bar of the tin in contact with the zinc, a communication be established between each of the bars of that metal, by the means of a communicating metallic substance, the savour will be manifested, in consequence of the formation of a symmetrical chain, by which the equilibrium is re-established.

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be perceptible, in consequence of the dispersion of the accumulated fluid.

Thus, to render a chain symmetrical, or to destroy it by the interposition of an insulating substance, will have the same effect relatively to the motion of the galvanic fluid. By the explanation which has just been given, it seems evident, that if, instead of rendering stationary the bar which touches the tongue, and moveable, the one which is held in the hand, the operation be performed inversely, the savour will be felt in contrary circumstances; seeing that the current will, in every such case, take an opposite direction.

When the extremity of the moveable bar is plunged in water, the one which is held in the moistened hand being fixed, and in contact with the plate of zinc at the bottom of the vessel, the sensation is perceptible on the tongue. But if the former be plunged still deeper, so as to be brought to touch the zinc, the savour will be no longer manifested. On detaching it from the plate of zinc, without, however, withdrawing it from the water, the sensation is again produced; but ceases as soon as the bar is taken out of the water.

If the extremity of each of the two bars of tin be laid on a particular point of the tongue, the savour will be felt at the extremity of the moveable

able bar, the moment its other extremity is plunged in the water, that of the fixed bar being in contact with the plate of zinc. Secondly, by plunging the moveable bar still more deeply in the water, and bringing it in contact with the plate of zinc, the savour will be felt at the point of the tongue where it is touched by the other bar. Thirdly, the instant either of the bars is separated from the plate of zinc, without being, however, taken out of the water, the galvanic savour will be distinguishable at its point. Lastly, the one which was stationary in the first instance, still continuing so, if the moveable one be taken out of the water, the savour will be felt at the extremity of the former.

From the principles which have just been laid down, it is not difficult to conclude that, if a metal taken from the given series be employed as a bar, and one of those by which it is followed in that series, as a *communicator* plunged in water, the phenomena which take place in the preceding experiments will be entirely changed. Consequently, the cases in which, in the first and second of the above experiments, the sensation was manifested, are precisely those in which there should not be any sensation, under the circumstances above stated; and *vice versa*. It also follows that, in the third experiment, the cases in which the savour was perceptible at the extremity of

of the moveable bar, are those in which, under these circumstances, it should be felt at the extremity of the fixed bar, and *vice versa*; the current then invariably taking a contrary direction.

Having placed the nerves of the thigh of a frog on a plate of tin, terminated by a small cavity filled with water, and the muscles on another plate of tin exactly similar, if one of the extremities of an arc of zinc be brought in contact with the bottom of the cavity formed in the coating of the nerve, and if the other extremity of the arc be immersed in the water contained in the cavity of the coating of the muscle, the susceptibility of the organs will be found to be such, that the contractions will not ensue. By plunging the communicator, however, still more deeply in the water, in such a way as that it may touch the bottom of the latter of the above cavities, the contractions will be instantly manifested in the animal arc*. Having afterwards detached the arc of zinc from the bottom of the cavity of the coating of the nerve, without, however, withdrawing it from the water, the organ becomes motionless; but, as soon as the arc ceases

* By establishing a communication between the two plates of tin, by the means of a metallic substance, the same effect is produced.

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to be immersed in the water, it being at the same time still in contact at its other extremity, the contractions are again produced. This experiment was frequently repeated by our author, and was constantly attended by the same result. In the latter instance, however, the contractions were invariably weaker than in the former *.

If the arc of zinc be brought in contact with the coating of the muscle, at the same time that its other extremity is plunged in the cavity of the coating of the nerve, the thigh of the frog will be forcibly contracted. By immersing it still deeper, so as that it may reach the bottom of the cavity, the contractions will cease. In detaching it, the muscular movements are usually perceptible; but there are occasions in which the organ remains motionless.

The same results will be obtained as often as a more powerful metal is employed, to establish a communication between two homogeneous coatings, formed of a weaker metal. If coatings of a metallic substance possessing a greater capacity, be employed in conjunction with a commu-

* To the end that these experiments may constantly succeed, it is necessary to be very careful to employ organs the susceptibility of which has been weakened. The contractions will otherwise be manifested in each of the four cases of the above experiments.

 nicator,

nicator, or arc, which has a less capacity, the effects which will be produced will be diametrically opposite.

The experiments which have been thus detailed, lead to a very singular result, namely, that one metal may be distinguished from another, without being either directly seen or felt. In reality, by composing a chain in such a way as that it may be terminated by one of the metals described above, a current being formed which takes a particular direction, totally different from the one which it takes when the chain is terminated by another metal, it is easy to recognise any one given metallic substance. In this way M. LEHOT was enabled to distinguish a portion of zinc from a piece of silver, at the extremity of metallic threads several yards in length.

Our author's memoir is terminated by an exposition of the means which may be employed, to augment the effect of each of the chains to which his inquiries were directed. If several analogous chains, consisting of two metals, be united by humid substances, and disposed in such a way as that they should all equally tend to give the same direction to the fluid, these partial chains, acting independently of each other, will each of them put in motion the quantity of fluid it would have acted on, had it been alone. Consequently, these collective chains will

will give motion to a greater quantity of the fluid, than any partial chain; and this will take place, in an augmented ratio, according to their number.

In a chain formed of analogous metallic arcs, connected by humid substances, and composed of two metals, the current is directed towards that particular metal which precedes the other. If the arcs be formed by a succession of three different metals, the current takes such a direction as it would assume, provided there were in each of the arcs the two extreme metals only.

If a brass wire be attached to each of the extremities of chains formed by a succession of arcs, consisting of zinc, copper, and a humid substance; of zinc, plumbago, and a humid substance; of zinc, lead, and a humid substance; or of lead, plumbago, and a humid substance; and if the circle be closed by plunging the two extremities of the brass wires in water impregnated with the nitric or sulphuric acid, in such a case the extremity of the wire which is attached to the least potent metal, will be covered with a layer of copper, at the same time that the other wire will be dissolved. This phenomenon has been repeatedly noticed in galvanic experiments, and is merely mentioned here to shew that, in this case also, there is a constant

stant relation to the direction of the current of the galvanic fluid; a fact which our author has principally aimed to establish. He expresses his conviction that he has sufficiently developed the laws of the motion of that fluid.

CHAP. XI.

Report made to the French National Institute by M. HALLE—*The composition of the animal and exciting arcs considered under its various modifications—The theory of* VOLTA *combated—Experiments made by* HUMBOLDT *in the presence of the Commissaries of the Institute.*

TOWARDS the close of the year 1798, a commission was appointed by the French National Institute, to examine the different galvanic experiments which had been made, and to ascertain their effects and results. The commission was composed of the most distinguished French physiologists, aided by the celebrated VENTURI of Modena, and, in one particular part of its researches, by M. HUMBOLDT, with whose profound physiological knowledge our readers have already been made acquainted. The following is an analysis of the report, which was drawn up by M. HALLE.

It sets out by observing, that, to produce the effects which characterize the animal property called galvanism, it is necessary, in general, to establish, by the means of galvanic instruments,

a com-

a communication between two points of contact, at a greater or less distance from each other, in a series of nervous and muscular organs. It results from hence, that the entire system of this communication represents, at the moment of action, a complete circle, divided into two portions, the intersections of which are at the two points of contact; one of these portions being formed by the organs of the animal, by which the influence is to be received, and the other depending on the instruments, by the means of which this influence is produced. These two portions of the complete circle are denominated in the report, the former the *animal arc*, and the latter the *exciting arc*. Relatively to the exciting arc, it ought to be observed, that it usually consists of several distinct portions, some of which, being placed beneath the parts of the animal between which a communication is to be established, are called *coatings*, *supports*, &c.; and the others, which are intended to produce the communication, by their continuity with the former, are denominated *communicators*.

It is on these considerations that the report of the experiments made by the commission is divided into six articles. In the first, the result of the various combinations and dispositions of the parts of which the animal arc is composed, is investigated. The second contains an exposition

tion of what the commission had observed, relatively to the nature and respective dispositions of the *exciting arc*. The third describes the most remarkable circumstances, relatively to the phenomena *extraneous* to the composition of either part of the galvanic circle, the influence of which had either determined, varied, or counteracted the success of the experiments. The fourth article contains several trials on *the means proposed to vary, enfeeble, or re-establish the susceptibility* of animals, in galvanic experiments. In the fifth a small number of experiments are brought together, the aim of which was to subject to a rigid *comparison*, the relations which several naturalists had conjectured to subsist between *the galvanic and electric phenomena*. Finally, the sixth article details the experiments repeated by M. HUMBOLDT in presence of the commission, which, when compared with those that had been precedently made, were found to present several important modifications.

Each of the above articles contains the reflections to which the experiments it contains gave rise, and the consequences which were naturally to be drawn from them. The following are the principal results.

In discussing, in the first article, the subject of the essential parts of the animal arc, in the galvanic circle, and of the dispositions of these parts,

parts, relatively to each other, the reporter, M. HALLE, enters into a detail of the experiments made on the different relations between the nerves and the muscles in which they are distributed; of those in which the nerves were tied or cut, the ligature or the section being comprised between the extremities of the arc; of those made on the nerves, which, having been taken from different parts, and from different animals, had been brought together and united in the same arc; of those made on the nerve alone, or on the muscle alone, comprised between the extremities of the exciting arc; of those in which bits of flesh, &c. were interposed in the animal arc; and, finally, of the experiments made on animals in their entire and unprepared state. The conclusions drawn from the aggregate mass of these experiments are eleven in number, and are briefly as follows:

1st, The animal arc may be formed either by nerves and muscles contiguous to each other, or by nerves alone.

2dly, Its essential part must consequently reside in the nerve.

3dly, All its parts ought, in general, to be continuous or contiguous to each other.

4thly, It is not interrupted by the section, or by the ligature of a nerve, provided the parts tied or divided are contiguous to each other.

5thly,

5thly, The diversity of the parts brought together in the formation of the animal arc, does not prevent its entireness, provided there be a contiguity between all the parts.

6thly, This entireness, when destroyed, may be re-established by the interposition of a variety of non-animal substances, and more especially by metals, provided the contiguity of all the parts be invariably maintained.

7thly, The muscular organs are constantly those in which the nerves comprised in a complete animal arc are definitively terminated. It results from hence, that the muscles which are affected, are invariably those that answer to the extremity of the arc most distant from the origin of the nerves of which it is composed.

8thly, When the origin of all the nerves which compose the animal arc, is brought towards one of its extremities, the muscles alone which answer to the other extremity, are subject to the galvanic convulsions.

9thly, When an animal arc is composed of several different systems of nerves, the origins of which correspond with the middle of the arc, the muscles of each of these systems are equally acted on, at its two extremities.

10thly, Several of the experiments which were made by the commission, tended to demonstrate the fallacy of the opinion of those who ascribe the

the galvanic phenomena to the concurrence of two different and corresponding influences, on the part of the nerve and of the muscle. Their results manifested, that the above physiologists had formed an erroneous judgment, when they compared the relations subsisting between the nerve and the muscle, in the phenomena of galvanism, to those of the internal and external coatings of a Leyden phial.

11thly and lastly, The covering of the epidermis, in entire and unprepared animals, is an obstacle to the development of the effects of galvanism. When, in consequence of its extreme tenuity, it does not interrupt them altogether, it weakens them in a very sensible manner.

The second article of the report treats of the parts of the exciting arc, and of their relative nature and dispositions. It is divided into seven sections, the first of which contains the experiments made with metallic substances, according to their nature and diversity, the exciting arc being formed of two or three different metals, or of a still greater number, but invariably different; of two metals in two or three portions; or of a single metal. Next follow the experiments made with metallic alloys, in different proportions; with amalgams; with different metallic combinations; with various kinds of mineralized metals;

metals; and with their oxyds. Lastly, the trials were made with metals rubbed against each other, and with carbures, sulphures, phosphures, and metallic oxyds, introduced as coatings into the arc.

The second section describes the experiments made with charcoal and carbonated substances, which, next to metals, merit a particular notice, relatively to their use in the formation of the exciting arc. The employment of idio-electric substances in the above arc, namely, of jet, asphaltes, sulphur, amber, sealing-wax, the diamond, and basaltes, the result of the trials on which forms the subject of the third section, constantly tended to intercept the galvanic phenomena. Air was productive of the same effect. Water, and humid substances in general, which are considered in the fourth section, when employed intermediately, in establishing the communication, determined by their interposition, in a very remarkable manner, the galvanic effects. In the fifth section an account is given of the experiments made with the animal substances by which the exciting arc was formed; and the sixth section describes the experiments relative to the extent of the surfaces of the parts of the arc in question. These experiments demonstrated that, in these intermediate substances, the augmentation of their extent, and more particularly of their

their surface, produced a very sensible difference in the intensity of the effect. The seventh section treats of the relations of the exciting faculties, between the different parts of the exciting arc.

The reflections made by M. Halle, on the experiments described in the above article, tend to prove as follows:

1st, That the disposition of the exciting arc, the most favourable to the galvanic effects, is the one in which it is made to consist of three parts at least of a different nature, selected from among metals, water and humid substances, carbonated substances, and animal substances deprived of the epidermis.

2dly, That the above arc appears, notwithstanding, to be efficacious in a certain degree, when it is merely formed of a simple substance of a suitable nature.

3dly, That the smallest difference in the nature of the parts, is sufficient to restore the efficiency of which it has been deprived by the identity of the substances.

4thly, That it may be completed by substances calculated to form the animal arc.

5thly, That its efficiency may be suspended by the separation, or at least by a sufficient distance between the parts of which it is composed.

6thly, That the smallest degree of humidity suffices

suffices to unite the parts of the exciting arc, and to determine the effects they are intended to produce on the animal arc.

7thly, That the influence of the state of the atmosphere, and of the surrounding circumstances, may be very powerful in the more or less successful production of the galvanic phenomena.

8thly, That the experiments made on the animal arc, and on the exciter, relatively to the comparative effects of animal substances, whether stripped, or covered by the epidermis; together with those made on the epidermis itself, either in a dry or moistened state, seem to warrant the conclusion that the latter substance ought to be considered as one of those by which the effects of the exciting arc are either weakened or intercepted. It is likewise, as well as the hair, and the bristles of certain animals, to be considered as belonging to the substances which partake of the nature of those denominated idio-electrical.

9thly, That the substances which may be made to enter into the formation of the exciting arc, are, for the greater part, comprised among those which are classed as substances capable of being employed as conductors of electricity; while those which tend to interrupt the arc, belong, for the greater part, to the class of substances stiled idio-electrical, or which are known

to retard the transmission of electricity. This proposition is, however, liable to great exceptions, as has been demonstrated by the experiments made by M. HUMBOLDT.

10thly and lastly, That the galvanic effect is in a certain ratio, not only to the nature of the parts of which the exciting arc is formed, and to their respective dispositions, but likewise to their extent, and more particularly to the size of the surfaces by which the effect itself appears to be transmitted.

The third article of the report refers to the causes which are extraneous to the composition of the galvanic circle, as well as to the two arcs of which it is composed, and which have, nevertheless, an evident influence on the result of the experiments. These causes and circumstances relate, in the first place, to the state itself of the contractile parts of the animal, subjected to the experiment. Secondly, to the mode of producing the contact by which the communication is established. Thirdly, to the influence which the experiments themselves have on each other, by the mere effect of their succession. And, fourthly, to the media in which the operations are performed. The article which is now under consideration is thus divided into four sections. The object of the first section was especially proved by the result of the experiments,

periments, made either with an identity of all the parts of the exciting arc, or simply with that of the coatings. The circumstances under which the susceptibility of the animal is diminished, gave rise to the ascertainment of several phenomena which would not otherwise have been observed, and the greater part of which are exposed in the second section, in which the influence of the mode of the contact, on the success of the experiments, is discussed. The variations of the contact are arranged as follows: First, a change is made in the disposition of a coating, or in that of the animal parts themselves. Secondly, the communicator is either brought nearer to the parts, or made to recede from them. Thirdly, the effect is produced by the rapidity of the contact, or by the hasty mode in which the communicator is withdrawn. Fourthly, it is produced by the simple change of contiguity, without any interruption of the contact.

The members of the commission having successively made a great diversity of experiments, relatively to the influence they have on each other, by the mere result of their succession, were soon convinced that several of them had so marked and decisive an effect, on the susceptibility of the animal, that they seemed to determine, in a very sensible manner, either the suc-

cess or the failure of the experiments by which they were followed. The experiments had hitherto been made in the common atmosphere; but they now proceeded to a new series, made beneath the water, and in an electrical atmosphere, which proved that one of the conditions the most capable of influencing the success of the experiments, consists in the nature of the media in which the processes are performed.

The experiments detailed in the above article led to the following reflections;

1st, That the galvanic influence appears, under many circumstances, to be excited by exercise, to be exhausted by a continuance of motion, and to be recruited by repose.

2dly, That the great variety of causes which appear to influence the result of galvanic experiments, and to contribute either to their success or failure, require the utmost caution in pronouncing affirmatively or negatively, unless a certainty has been acquired, that all the circumstances by which they are influenced have been duly appreciated.

3dly, That one of the circumstances most directly in proof of what has just been advanced, is the particular relative to the continuance of the galvanic spasm, when the communicator, held in the hand, appeared to be constantly directed towards the same point of contact. On this

this occasion it was demonstrated, by the cessation of the spasm at particular intervals, that a real change had taken place in the contact, notwithstanding the apparent immobility of the communicator. From hence, observes the reporter, it may be concluded, that the smallest change in the respective situations of the parts of the galvanic circle, and of the exciting arc, may produce an effect on a susceptible animal, and influence the successful issue of the experiment, unless an attention be paid, in this respect, to the slightest variations.

4thly, That the experiments relative to the connexion between the galvanic movements and the approach or retirement of the conductor, tend likewise to support the preceding proposition, and prove that the shortest intervals of time ought not to be lost sight of, in experimenting, and should not only be observed collectively, but likewise studied in their succession, during the entire continuance of the operation.

5thly, That, in the formation of the exciting arc, there appear to be both enervating and corroborating dispositions, several of which not only possess a positive or negative influence at the moment, but likewise dispose the animal to a greater or less degree of susceptibility in the experiments that ensue.

6thly, That it is equally essential to the ex-

actitude of the experiments, and to their due appreciation, to ascertain the state of the animal, as well as the mode in which it has been kept until the moment of trial, and likewise the state of the atmosphere.

7thly, and lastly, That it is a desirable object to physiologists, to arrange the different kinds of experiments in the order of their efficiency, and to form in this way a galvanic scale, which would lead to the ascertainment of the degree of susceptibility residing in an animal, taken in such a state, and in such a disposition, as well as to a knowledge of the experiments to which it ought to be subjected, according to its more or less susceptible condition. Such a classification of the experiments would enable them to judge, how far the success or failure of an experiment might give rise to certain conclusions, absolutely negative or affirmative.

The fourth article of the report relates to experiments on the means of varying, enfeebling, and re-establishing the susceptibility of animals, in galvanic experiments. To complete the classification of the causes by which the success of the experiments may be influenced, it was likewise necessary to ascertain, independently of the circumstances which refer to the mode of operating, to the state of the animal, and to the effects resulting from the intermediate bodies, the action of

of the different substances capable of developing or suspending the susceptibility of the nervous and muscular organs. This article is composed of three sections, the object of the first of which is the influence of electricity on the susceptibility of animals subjected to galvanic trials. The second considers the effects of several liquid substances on the galvanic properties of the muscular organs. And the third treats of the influence of the different causes by which asphyxies are produced on the galvanic effects. This section is extracted from the experiments made at the School of Medicine in Paris.

1st, A single experiment sufficed to demonstrate the property by which the electric spark re-establishes the susceptibility of animals, exhausted by repeated experiments.

2dly, The liquids which were employed to ascertain the galvanic properties of the muscular organs, consisted of alcohol and the oxygenated muriatic acid, applied to organs exhausted by a series of experiments; together with solutions of potash and opium. In all the trials, the most efficacious metals, such as silver and zinc, were employed as coatings. The experiments which had been made by M. Humboldt, and in repeating which his processes were strictly followed, did not, however, afford results conformable to those

those he had described. On this subject the above physiologist, who was present, observed to the members of the commission, that experiments of this nature, the object of which was to ascertain shades of difference more or less difficult to the perceptions, should have been made at a colder season of the year.

3dly, The experiments described in the third section, relatively to the effects of asphyxies on the muscular organs, were made on animals with cold blood, some of which were brought into a state of asphyxy, either by submersion, by strangulation, or by the action of the different gases, while the others were made to perish *in vacuo*, or by the means of electrical discharges. The object of these experiments was to make a relative comparison of each of the phenomena, and of each of the effects, of the different kinds of asphyxy, taking all possible care to ascertain, in the animals brought into that particular state, the condition of the muscular system, relatively to the effects of the galvanic influence. The experiments were made with an exciting arc composed of three different metals; and the animals subjected to them, were rabbits and guinea-pigs, (*cavia* cobaya.) The state of the susceptibility of the nervous and muscular organs, presented a great variety of phenomena, according

according to the difference of the causes of the asphyxies, and the mode in which they operated. The following is a summary of the results.

In the first place, the susceptibility was entirely annihilated by asphyxies in the sulphurated hydrogen gas, and by those produced by the vapour of charcoal, by the submersion of the animal, and by its suspension by the hinder feet. Secondly, its progress was retarded by asphyxy in the pure carbonic acid, beneath a mercurial apparatus. Thirdly, it was weakened, but not annihilated, in the case of asphyxies produced by the sulphurated hydrogen gas, after it had lost a portion of its sulphur; by the ammoniacal gas; by the azote gas; and by the gases exhausted by respiration. Fourthly, it remained in an unaltered state, after asphyxies produced by a submersion in mercury; by the effect of the pure hydrogen gas; by the carbonated hydrogen; by the oxygenated muriatic acid; by the sulphuric acid; by strangulation; by the exhaustion of air in the pneumatic machine; and by the discharges of an electrical battery.

At the close of the inferences drawn from the experiments made on the comparative effects of asphyxies, are the reflections which result from these effects, and which tend to prove:

1st, That if asphyxies in general resemble each other, by the privation of a respirable atmosphere,

and

and by the suspension of the functions of the lungs and of the circulation, they vary greatly in their other effects, according to the nature of the substances by which they are caused.

2dly, That, among these causes, there are some which act very profoundly, penetrating, at the same moment, all the parts of the nervous and muscular systems; while others have but a superficial action, and merely produce a pulmonary asphyxy.

3dly, That one of the most remarkable changes consists in the variations to which the galvanic susceptibility is liable.

4thly, That the state of muscular irritability, ascertained by the means of substances, the mechanical action of which produces the contraction of the muscles, by irritating them, does not always correspond with the state of their susceptibility for galvanism. There is, indeed, in certain cases, a marked difference between the two states.

5thly, and lastly, That the causes of asphyxies do not act in the same manner, on all the parts of the muscular system: and that the heart is very frequently in a state entirely different from that of the other muscles.

The fifth article of the report contains an account of several comparative trials between the galvanic and electric phenomena. It is a well known fact, that it was owing to the obser-

observation of the movements of frogs, at a certain distance from an electrical machine from which sparks were drawn, that GALVANI was, as it were involuntarily, led to the important discovery which has since occupied so much of the attention of naturalists. The members of the commission accordingly deemed it essential to examine the extent of the electric influence on the animals they were about to subject to galvanic experiments, before they should proceed to inquire into the effects of one of these influences on the phenomena produced by the other. The objects of these experiments therefore were to determine the susceptibility of animals for the influence of electricity, and to form a comparison between this susceptibility and that which they have for galvanism. The greater part of these experiments, and more particularly those made in a watery medium, together with the results of those made with homogeneous coatings, and with the exciting arc, gave inductions which, in the opinion of the members of the commission, if they did not destroy, invalidated, at the least, a great part of the theory of VOLTA, relatively to the influence of the respective electricities of metals on the phenomena of galvanism. They, at the same time, seemed to strengthen the doubts which have been entertained, as to the identity

identity of the principles of electricity and galvanism.

The sixth article of the report contains a detail of the experiments which were made, in the presence of the members of the commission, by M. Humboldt, and which are chiefly analogous to those detailed in the preceding articles. Their object was, in the first place, to ascertain the effect of the galvanic processes on the motions of the heart. Secondly, the effect of the ligature of the nerves. Thirdly, the effect of evaporable substances, introduced into the different parts of the exciting arc; and of the symmetry, either established or destroyed, between the parts by which the extremities of the above arc are formed. Fourthly, the galvanic atmospheres. Fifthly, the substances which are powerful conductors of electricity, but which, nevertheless, suspend the galvanic commotion. Sixthly, the comparative influence of electricity, on the electrometer, and on the nervous and muscular organs. Seventhly, the indications of several of the experiments suggested by M. Humboldt, the results of which appeared to require new trials, the season in which they were made not having been favourable, for the three following reasons: First, because they require a great susceptibility in the animal. Secondly, because the time when this susceptibility

lity is the greatest, is towards the close of the winter, or at the commencement of the spring, the epoch when the animals which were subjected to the experiments, revive from their torpid state, and are on the point of copulating. And thirdly, because, when that epoch is past, and the period of copulation at an end, the susceptibility is diminished. While the copulation is going on, it was stated by M. HUMBOLDT, that it is, *cæteris paribus*, in the male frog, greater in the anterior extremities, with which the animal embraces the female, than in the posterior extremities; and that, at every season, it is in general greater in the females than in the males, more particularly in the hinder extremities. Several phenomena, announced by HUMBOLDT, seemed to demonstrate that there are experiments which do not succeed, unless at the time of the highest susceptibility in the animal.

The experiments to which we have referred, and the reflections annexed to each of the articles, give a precise idea of the principal properties by which the galvanic fluid is characterized. They hold out the prospect of a vast field of observations, in which a new system of phenomena appears to develope, in a new and varied light, the *ensemble* of beings endued with life, sensation, and motion. According to these experiments, the galvanic phenomena seem to demonstrate

strate, in the animal organization, a principle the nature of which will, perhaps, be long unknown, but in which evidently resides the essence of the mutual agreements between the nervous and muscular systems. We may furthermore perceive the evidences of a sensible analogy between galvanism and electricity, in the mode in which the effects of this principle are propagated, between the parts of the living animal; in its progress, and in the instantaneous rapidity of its influence; in the artificial means of communication which it obeys; and in the relations of this communication with the two orders of substances, by the former of which it is transmitted, while it is suspended by the latter.

Whatever this analogy may be, it is evident, however, that it is as yet far from bearing the stamp of a perfect identity. Without entering, therefore, into any further reflections relative to the nature of the galvanic principle, it will suffice to observe, that the experiments by which it is pointed out to us, appear to demonstrate, with a new evidence, a phenomenon residing in the animal economy, already known, it is true, but which will in future be less difficult to appreciate. By this phenomenon we are taught, that the characteristic marks of life may subsist, in an insulated way, in the different parts of the animal organization, for a long time beyond the term

when

when the life of the totality of the parts is destroyed, and when the animal, consequently, ceases to exist, because the functions which maintain the correspondence of the whole, and of the parts, namely, the respiration and the circulation of the blood, are no longer performed.

"This is not all," adds the reporter of the commission: "By making us more intimately acquainted with the effects of the causes by which these functions are intercepted, and which either suspend or annihilate the life of the animal, by the state of asphyxy they induce, the galvanic phenomena enable us to discover, between their deleterious qualities, the distinctions dependent on the difference of the attacks which these causes make on the vital faculties, and the degrees of which refer, not only to the intensity, but likewise to the nature of their action. May not the acquisition of this knowledge hereafter lead us to the improvement, not only of the diagnostic, but even of the treatment of asphyxies?"

To how many discoveries, in the practice of medicine, may not this principle lead? Whatever is hypothetical in that science, has an unquestionable utility, seeing that it contributes greatly to enlighten both the diagnostic and the prognostic. But the knowledge which is established on an experimental basis, followed up by reason-

ing, is infinitely superior. If there be an intimate connexion between the two, and if each of these acquirements has its relative value and advantages, it must be agreed, at the same time, that the former is rendered more perfect by the latter. It may therefore be said, that what is practically founded in medicine, is the completion of the curative art. It is the only knowledge in which the generality of persons confide.

CHAP. XII.

Experiments made by Professor ALDINI *on cold-blooded animals—He endeavours to combat the doctrine of* VOLTA, *apparently with little success—He is the first to excite convulsions in cold-blooded animals, by the influence of warm-blooded animals without the intervention of any metallic substance.*

REPEATED mention has been made in this work, of Professor ALDINI, nephew to the celebrated GALVANI. The following is a brief account of several of his most interesting experiments.

About the middle of October of the last year, (1802) this naturalist made several experiments in presence of the Galvanic Society of Paris. It will suffice to recapitulate the principal phenomena which were observed.

1st, Several frogs, which had been recently prepared, successively exhibited the phenomenon of a very sensible contraction, without any metallic substance being interposed, and by the simple contact of the nerves with the muscles.

2dly, The animal arc was several times produced, and made sensible, by similar disposi-

tions to those detailed in the preceding experiment.

3dly, Simultaneous muscular contractions were produced by the application of silver alone, in three frogs recently prepared, and placed, in the same direction, at the side of each other. The experimenter being, however, desirous to prove that the fluid by which the animals were acted on, was not ascribable to metallic electricity, changed the position of the intermediate frog, by placing the superior extremity of its trunk in a parallel line to the inferior extremities of the other frogs. A contraction being observed to ensue in the latter, without any such contraction being noticed in the intermediate frog, it was necessarily concluded that, as the fluid did not take the shortest route of communication, it could not be the electric fluid contained in metals, one of the general laws of which does not allow it to deviate from that route.

The results which were drawn from these facts and phenomena were as follows:

1st, That in analogous experiments, the animal fluid supplies the place of the electric fluid propagated by metals.

2dly, That this animal fluid needs no other conductor beside the organized parts of the animal.

3dly, That the nerves and muscles are the

most

most certain conductors of this fluid; and that, consequently, the experiments made, either on the nervous plexus, or on the origin of the nerves, cannot fail to present the most striking and decisive effects.

4thly, and lastly, That the different metals, in whatever way they may be applied, in experiments analogous to the above, perform no other office than that of favouring, in a greater or less degree, the propagation of the universal galvanic fluid, which penetrates readily, in preference to all other fluids, the nervous and muscular parts of organized bodies.

The following are the principal results of a series of experiments made by our naturalist about the same time, in the presence of the members of a commission appointed for that purpose by the French National Institute.

1st, Having laid bare the sciatic nerves of a frog, in the customary manner, to the end that they might be subjected to the action of the coatings, and of the metallic circle, he brought in contact with the denudated nerves, the muscular parts of the thighs and paws of the animal.

The contractions ensued in the same way as in the customary galvanic experiments.

2dly, Holding the muscular parts of the thighs of the animal in one of his hands, he touched with a finger of the other hand the suspended

nerves. The contractions ensued in the same way as if the galvanic circle of metals had been formed.

3dly, Having requested one of the company to hold a frog by its muscular parts, and applied his finger to the nerves, without giving his hand to the person in question, the contractions did not ensue. They were manifested, however, as soon as he presented his hand, the finger of the other hand being applied to the nerves of the frogs. This experiment was repeated on several of these animals.

These experiments were shortly afterwards repeated, with similar results, in London, at Mr. WILSON's anatomical theatre, Great Windmill-street. On this occasion the ingenious Mr. CUTHBERTSON assisted Professor ALDINI in arranging the apparatus; and the anatomical preparations were furnished by Mr. HUTCHINS, a medical student. A considerable concourse of persons of rank and fashion were assembled.

It would appear from what has been stated above, and from what has since been attempted by Professor ALDINI, that he has long laboured under an apprehension, least the theory of his uncle, GALVANI, should be lost in the blaze of VOLTA's discoveries. He has, therefore, endeavoured to support his relative's doctrine, by a variety of experiments arranged with much inge-

ſuity. Finding it to be too arduous a task to oppose, in a direct way, the principles of VOLTA, his attempts have been chiefly directed to a reconciliation of the two systems so diametrically opposite to each other. It cannot, however, be said that his efforts have been attended with all the success he expected to derive from them. ALDINI appears to be the first naturalist who has succeeded in exciting convulsions in cold-blooded animals, by the influence of warm-blooded animals. Thus, *Plate* II. *Fig.* 1, represents; first, the head of an ox recently killed; next, a finger of one of the hands of the operator moistened in salt and water, thrust into one of the ears; and lastly, a prepared frog in the other hand. On its spine touching the tongue of the ox, the convulsions were produced.

Our naturalist deduces from hence, that there is a galvanic fluid peculiar to the animal machine, independently of the influence of metals, or of any other foreign cause. So also, if a prepared frog be held by one hand moistened with salt and water, and the crural nerves be applied to the tip of the experimenter's tongue, the convulsions will take place.

A curious circumstance is noticed by ALDINI. A frog being held as above, if, instead of its being applied to the tongue, the moistened finger of the other hand be brought towards the crural

nerves, before the contact is effected, the above nerves are observed to approach the finger. Professor FONTANA has likewise noticed this phenomenon, and has promised to favour the world with his opinion on this interesting subject.

Our naturalist now proceeds to shew that metals are in no way necessary, in the production of these effects. He, notwithstanding, allows that when heterogeneous metals are employed, the convulsions are more powerful.

He has attempted to shew that a single metal will suffice, for instance, quicksilver, to produce the electric phenomena. VOLTA denies the deduction ALDINI has drawn; and observes that mercury, the surface of which is in a partial state of oxydation, constitutes in an electrical sense two different metals, the portion beneath the oxydated surface answering to one of them, and the surface itself, thus altered, to the other.

ALDINI has introduced several experiments, to prove a degree of similarity in the Leyden jar, in the Voltaic pile, and in animal substances, relatively to the absorption of principles from the air. In this analogy he has erred considerably. The Leyden jar, when charged, far from absorbing any principles from the air, displaces an adequate bulk of that fluid, in consequence of the admission of electricity. When it is placed over water,

water, in proportion as the jar becomes uncharged by an exposure to such a conducting medium, the water necessarily rises within. This is not the case with the Voltaic pile, or with the exposure of animal substances, which absorb the oxygen from the atmospheric air.

Professor ALDINI details several experiments to shew the influence of galvanism on the vital powers. As they are without novelty, it is unnecessary to particularize them. He very erroneously supposes, that the heart is not affected by galvanism any more than any of the involuntary muscles. The contrary of this has been fully demonstrated by other naturalists.

In the medical application of galvanism, as he has not had the advantage of a professional education, he has been much limited. The two cases of melancholy madness he has given, are, however, very curious, and well worthy the attention of medical persons. So far as his work refers to the influence of galvanism on the secretions, no practical deductions can be drawn, the cure of a diseased gland not being effected by any changes in the secretions, but by a change in the morbid action of the gland itself.

Although our naturalist has not advanced any new principle, yet he has, with considerable ingenuity, elucidated GALVANI's theory, by several curious and beautiful experiments. It does not

not appear that he has had all the justice done him by the philosophers on the Continent, which he appears to merit.

In *Plate* II. *Fig.* 1, the manner of producing convulsions in cold-blooded animals, by the influence of warm-blooded animals, is represented. The right hand of the experimentalist is placed in the ear, previously moistened with salt and water, of an ox's head, while in the other hand a prepared frog is suspended by the foot, and the sciatic nerves brought into contact with the ox's tongue. In the muscles of the frog convulsions are immediately produced.

Fig. 2, represents a prepared frog, suspended on a metallic wire, and, parallel to the animal, a metallic chain. When the receiver is exhausted of air, on pushing down the rod in such a way as that the nerve of the frog and the chain may touch the metallic plate at the bottom of the receiver, the frog is equally convulsed as in open air.

Fig. 3, represents an experiment formed with a view to controvert the theory of VOLTA, as to the influence of dissimilar metals. The glass vessel, A, contains mercury, on which a prepared frog is laid; the spine, B, being raised up by a thread, C, every time it is brought into contact with the mercury, the convulsions take place. *Vide p.* 140 *of* ALDINI'S *work.*

Fig.

Fig. 4, represents a living frog placed in an exhausted receiver, the animal being tied to a plate of silver by a silken string, and having a piece of tin-foil on its back. As often as the circuit is completed the convulsions ensue.

CHAP. XIII.

Review of the most interesting attempts which have been made, to apply the principle of galvanism to the cure of diseases.

NOTWITHSTANDING the very interesting philosophical researches to which it has given rise, if galvanism had not been found to supply resources in particular diseases, and to suggest a more certain method of cure, it would have fallen into speedy oblivion, and have shared the fate of *mesmerism*, and other more recent doctrines, of greater curiosity than utility, with which several empirics have contrived to enrich themselves, and to delude society. If a zealous activity, and a constant perseverance, in galvanic experiments, directed towards the above salutary aim, had been able to ensure a complete success; and if several particular accidents, dependent on the constitution and impatience of the sick, together with certain circumstances which could neither be foreseen nor guarded against, had not frequently thwarted and changed the nature of experiments which promised to be decisive, the healing art would long ago have been

been enriched by a new and effectual method of cure. The physicians and naturalists who have combined their efforts, with this laudable intention, would thus have diminished the number of the diseases which afflict humanity, or would, at the least, have afforded an effectual relief in certain particular cases.

This new tract of medical science has been pursued with more or less promptitude or slowness, and with a greater or less degree of success, according to the intelligence of the competitors. An unusual zeal has been latterly displayed, in contriving the means to surmount the obstacles by which the progress of the discovery has been retarded; and every thing may be effected by time. Some little dependence may also be placed on chance, a word which, however it may be devoid of meaning, has, nevertheless, made a conspicuous figure in almost every discovery, and in that of galvanism among others. How often, indeed, have experiments, repeated with a perseverance which has bordered on obstinacy, led to unexpected results, very different from those which were presumed.

To direct those who may wish to prosecute new inquiries on galvanism, as it refers to the curative art, we shall take a summary view of whatever is most interesting on that head, in the researches which have already been made. It

will

will be seen that they furnish, at the least, a few glimpses of the hope of success. We shall begin by an exposition of the ideas of the author of the discovery of galvanism, relatively to its application to the healing art.

It was observed, at the commencement of this work, that the theory of GALVANI, notwithstanding he had, in his endeavours to establish it, exhausted all the resources of his inventive genius, was unable to resist the multitude and evidence of the real and incontestible facts by which it was opposed, and, in a manner, overwhelmed. We shall now see whether he was more successful in the principal extensions he gave to his first hypothesis, in the investigation of the causes of diseases. If he was led away by his lively and ardent imagination, let it not be urged against him as a reproach; and be it remembered, that the lapses of a celebrated man are constantly interesting, insomuch as they are lessons to posterity.

We shall now proceed to an inquiry into the particular ideas of GALVANI, relative to the production of rheumatic affections, of the nervous sciatica, of convulsions, and of the tetanos. He endeavoured to account for the acute and lasting pains, with the muscular contractions inseparable from them, which accompany violent rheumatic affections, and more particularly the nervous

sciatica,

sciatica, by ascribing them to extravasated humours, become stagnant around the surface of the nerves, and acting, not only by the irritation caused by their presence, but likewise by a description of arc or coating, of a considerable extent, with which they furnish the electric fluid. In conformity to these ideas, he explained the causes of the frequent and fatal convulsions which are produced, wherever there is a collection of fluids, either between the brain and the *pia mater*, or between that membrane and the *dura mater*, or in the ventricals of the brain, or between the spinal marrow and the vertebral canal, or, lastly, between the nerves and their coverings.

He was likewise of opinion that this phenomenon might result from the changes produced in the layers of the non-conducting substance, with which, according to his hypothesis, the nerves are provided. These layers, in the point of view in which he saw them, are changed, either by an extraordinary diminution of their thickness, or by a depravation carried to such an excess, that, from having been non-conductors, they become conductors, either wholly, or in part. It may be in this way comprehended, how it is that the electrical torrent, having found a passage through this substance, which it could not before permeate, must acquire a considerable

degree

degree of energy, and produce, by a mechanism of this nature, powerful and extraordinary contractions. The tetanos is, according to GALVANI, produced pretty nearly in the same manner. In this affection there is one peculiarity, namely, that the irritation of a single nerve suffices to excite a spasmodic rigidity throughout the whole extent of the muscular system, as is frequently seen after the puncture of a nerve. As soon as the spasmodic movements have been induced, the slightest agitation of the patient's bed is sufficient for their reproduction.

After having endeavoured to account for the mode in which the muscular movements are produced, or augmented to an extraordinary degree, GALVANI attempted to explain, by the same theory, the diametrically opposite state, or, what amounts to the same thing, the absolute loss of the contractile faculty, from whence paralysis results. This disease he ascribed to the interposition of a non-conducting body, which resists the passage of the electric fluid, from the muscle to the nerve, and from the nerve to the muscle. Now, this effect will, according to him, be produced as often as an unctuous substance, or any other non-conducting matter, shall obstruct the nerves, or the membranes in which they are enveloped; as often as an acrid and corrosive humour shall have changed the texture

of

of the brain, and produced a congestion, &c. &c. He has agreed, however, that the palsies and apoplexies which are formed slowly and by degrees, are the only ones which can be explained in this manner. In comparing the phenomena of apoplexies and epilepsies with the effects resulting from the application of artificial electricity to animals, he notices the striking analogy between them, and observes as follows:—"If artificial electricity be conveyed to the head, nerves, or spinal marrow of an animal, by the means of the conductor of a Leyden phial, paralysis, apoplexy, and even death, will be induced, according as the phial is charged with a greater or less quantity of the electric fluid. If such effects result from common electricity, may it not be presumed that a sudden afflux of animal electricity towards the brain, may be productive of the most fatal consequences? May not the intensity of the diseases which ensue, be augmented, in these instances, by a change in the state of atmospherical electricity, more particularly when it is very abundant; seeing that, in such a condition of the atmosphere, the electricity of animals likewise abounds, as is proved by the violent and reiterated agitations they undergo?"

It may readily be conceived that the cause which Galvani has pointed out, will produce

these effects more readily, as well as more speedily, provided it attacks the cerebral organ in a direct way, than if it acts exclusively on the nerves. In the former case, idiopathic diseases will be produced, and in the latter, the diseases will be sympathetical. But, in either of these cases, the violence of the symptoms will be augmented, in proportion as the vitiated electrico-animal fluid shall have been accumulated in a greater abundance, either in the nervous, or in the muscular system. It is beyond a doubt, that these diseases are peculiarly fatal in aged persons, on account of the development which age produces in all the parts of the physical system, and, more especially, on account of the small portion of fluidity contained in the oleaginous substance of the nerves, as well as of a defective transpiration.

GALVANI endeavoured to support his hypothesis by what is observed in epileptic patients, at the moment the fit is coming on. The greater part of them then feel, as it were, a current of air, which either ascends to the stomach from the abdomen, or rises from the inferior extremities towards the brain. They sometimes give notice of the attack to the persons by whom they are surrounded, insomuch that, if the favourable moment be seized, and a strait ligature be made in the leg, the fit is frequently prevented

vented from coming on. Would it not appear that, by this application of the ligature, the transmission of the electrical current towards the brain is resisted ?

We shall now see what was GALVANI's opinion relative to the *modus operandi* of remedies, and to the manner of administering electricity. Agreeably to his hypothesis, the good effects which result, in these cases, from the application of different remedies, as well as of artificial electricity, are to be ascribed to the mode of their action on the animal fluid, whatever may be the change produced in the state of that fluid. He was therefore persuaded that the physician ought to govern his treatment by these indications. To have a competent idea, for instance, of the different modes in which electricity operates on the human body, it is necessary to pay attention to three particular circumstances. First, that artificial electricity acts promptly and violently on the animal economy, as happens in the experiment of the Leyden phial. Secondly, that it acts in a slow and successive manner, and appears to combine itself with the fluids of the humid body, when the application of it, denominated the *electric bath*, is made. Thirdly and lastly, that it has a peculiar action, when a given quantity of the electric fluid is drawn from the system, as occurs when it is negatively employed.

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The convulsive movements depend almost invariably, either on a vitiated and exuberant animal electricity, which, being excited by causes the nature of which is oftentimes very trivial, is propelled towards the brain and the nerves; or on certain acrid and stimulating principles, which transmit their action to the above organs. In the former of these cases, negative electricity will, according to the opinion of GALVANI, be found to be of the greatest efficacy; and, in the latter, a preference ought to be given to positive electricity, taking particular care to direct its influence, in an immediate way, to the diseased nerves.

On these considerations he endeavours to demonstrate that, in the treatment of convulsive diseases, nothing can be more important than to inquire, which of the two electricities, the positive or the negative, it is most proper to employ. The experiments which he made on this subject, prove that, when the atmosphere is overcharged with the electric fluid, there is constantly reason to suspect too great an abundance of animal electricity; and from hence arises the necessity, before the treatment of diseases by electricity is entered on, not only of subjecting the air to the test of electrometers, but likewise of paying attention to the state of the clouds, to the season, to the kind of wind which blows, to the

the lunar phases, &c. &c. It would appear by these experiments, that the mode which is preferable to all others, when the negative electricity is applied, is to establish a communication between the electric fluid which resides in the muscles of any given part, and the nerves of the part affected. This is the surest way to transmit the animal electricity from the muscles to the diseased nerves, and to expel the extraneous substances by which they are irritated. GALVANI afterwards expatiates on the advantages which may result from the application of atmospherical electricity, in stormy weather. In doing this, however, every precaution ought to be taken, and much prudence observed, in the mode of arming with conductors the diseased part.

Without attaching to the above theory, as it relates to the application of electricity to the cure of diseases, a greater importance than it merits, it is, notwithstanding, certain, that the experimental inquiries of GALVANI on this subject are not only conformable in their result with those of M. MAUDUYT, published in the Memoirs of the Royal Society of Medicine of Paris, but besides prove, that the influence of atmospherical electricity, and of artificial electricity, is infinitely greater than has been latterly thought. Let us therefore indulge a hope, that the data

 which

which have been acquired as to its mode of action, resulting from the galvanic researches of the different physiologists, will throw much light on the various modes in which it may be administered with greater efficacy than heretofore. They will, perhaps, in the sequel, develop the constant relations which subsist, between the variations of atmospherical electricity and the state of health, and between these variations and several diseases.

The application of galvanism to the healing art, has not, as may readily be conjectured, escaped the attention of M. CREVE. It is asserted by this celebrated naturalist, that he has employed galvanism, with a considerable degree of success, in distinguishing real death from apparent death, or asphyxy. On this subject he has published several very interesting details in his work on metallic irritation. He proposes to lay bare one of the muscles, for instance, the brachial biceps, or gastrocnemian, or even the great pectoral muscle, and to apply the silver and zinc, in a convenient form, to the muscular fibres themselves, in such a way as that the galvanic arc may be established. If the fibres contract, it is a proof that the irritability has not as yet been entirely destroyed; and, consequently, it cannot be asserted that the subject of the inquiry is really dead. But, should the contrary be the case,

case, there can be no longer any doubt of death having ensued.

The three following objections may be made to the above doctrine. First, that a partial death may exist in any one of the muscles pointed out, without being imparted to the rest of the body. Secondly, that the susceptibility to the galvanic stimulus may be annihilated, without the irritability being generally exhausted. And, thirdly, that the galvanic *stimulus*, applied in the mode prescribed by CREVE, is not the most powerful *stimulus* known, since the electricity of a Leyden phial, and the galvanic battery, act still more forcibly. These objections, to which it would be difficult to reply, render the efficacy of the plan proposed by M. CREVE very doubtful, as will be seen still more distinctly in the analysis of HUMBOLDT's production on the same subject.

The galvanic stimulus has been proposed by PFAFF in the treatment of several diseases, more particularly in that of the paralysis of the optic nerve. He speaks of the successful treatment of a case of hemiplegia, by the introduction of silver into the mouth, and the application of a piece of zinc to the palsied arm. The communication was kept up, without interruption, for the space of twenty-four hours, at the end of which time the use of the limb was in some measure restored. To diminish, he observes, on the contrary, the

 irritable

irritable state, in several spasmodic affections, it is necessary to inverse the application of the metals. The zinc should then be stationed as near as possible to the central extremity of the nerves, and the silver laid on their peripheric terminations.

HUMBOLDT's communication on the application of galvanism to practical medicine, was addressed to M. LODER. After five years of constant researches into the laws by which the phenomena of galvanism are governed, and into those which relate to the irritability of the nervous and muscular fibres, this celebrated physiologist was certainly enabled to decide on the application of these phenomena to practical medicine. After having agreed with M. LODER, that the principal advantage of galvanic discoveries, consists less in its direct application to the derangements of the animal economy, than in the light it may throw on the nature of the nerves, and on the energy with which they are endued, he proceeds to observe that, in an age like the present, when a slow and progressive progress in the sciences is considered as a stationary state; in an age, in short, when a desire is manifested to collect the fruits before the flowers are formed, the experiments which have, from the moment they were conceived and made, promised a speedy and immediate application to the healing art,

cannot

cannot have failed to attract the particular attention of the public, by whom such an application was in a manner anticipated.

It is thus that galvanism has been occasionally recommended as the criterion of death, and at other times as a powerful and salutary stimulus in the diseases of the nerves. But, when an idea was in the first instance formed, of the electric fluid and its properties, was it not immediately thought that, in its action on the human body, it would supply a remedy for all the diseases to which it is subject? In the same way, after having noticed the galvanic phenomena, it has been latterly apprehended that two pieces of metal, employed in a particular way, would, as it were by enchantment, recall to life those who have perished by asphyxy, restore sight to the blind, re-establish, in all cases of paralysis, the use of the limbs, and, in a word, produce more salutary effects than the faculty have been enabled to obtain, from the multitude of chemical, mechanical, and other remedies which have been employed for so many ages.

Our physiologist, who is not an enthusiast on this subject, examines coolly and without prejudice, what the medical science has a right to expect from galvanism, and subjects to a rigorous analysis the opinions propounded on this subject by the most distinguished naturalists. "Let it

it not, however, be forgotten," he observes, "that the science which is under our consideration, is still in its infancy, notwithstanding the time that has elapsed since its discovery. On the first occasion that soap-bubbles, filled with hydrogen gas, were observed to rise rapidly towards the ceiling of an apartment, the spectators were far from imagining that this phenomenon would furnish man with the means of elevating himself in the air, and of hovering with security over the ocean itself."

The first question examined by M. HUMBOLDT is, whether galvanism may be employed to distinguish the death which is merely apparent, from real death. At the time when a celebrated physician, HUFELAND, pointed out the danger of precipitate interments, an expectation was entertained that two pieces of metal, brought in contact with a nerve, would resolve the important problem of the life or death of an individual, an hour after he had appeared to have breathed his last sigh. BEHRENDS and CREVE were the earliest to direct their inquiries to this subject, and to make experiments on dead bodies. HYMLY and PFAFF strenuously combated the arguments and conclusions which the above naturalists drew from their experiments. "I have compared," says HUMBOLDT, "the facts related by CREVE, with the results that have come to my particular know-

knowledge, and have found that my observations do not accord with his conclusions." Our naturalist now proceeds to give the reasons which prevent him from considering galvanism as the true criterion of death. They are as follows:

1st, That the electric fluid still enables us to perceive indications of irritability in a nerve, on which galvanism has not any sensible effect.

2dly, That the galvanic trials cannot be made otherwise than on certain determinate parts of the body, in which the irritability may be destroyed, without our being allowed to conclude from thence that it is also annihilated in every other part of the nervous system.

3dly, That there are cases in which galvanism appears suddenly to have no effect whatever, on organs which were a little time before highly sensible to its application, and which were even in a convulsed state after its action had ceased.

4thly, That a possibility exists, of the parts which had been apparently deprived of their irritability for some time, recovering it afterwards to a certain degree. Alkaline solutions produce, in highly irritable organs, effects nearly similar to those which result from galvanism on those that are less so. It would therefore be very improper to consider that the organ in which alkaline substances do not produce any sensible movement, is absolutely deprived of its irritability; and

and what is true respecting them, may be equally so respecting electrical and galvanic stimuli.

Our author gives an account of several curious experiments, to which he paid the most scrupulous attention, made on different animals. Their results have fully persuaded him that very slight electrical shocks sometimes stimulate muscles on which zinc and gold do not produce the smallest effect. He is persuaded that the irritated muscular fibre contracts in the form of an arc, and the inanimate fibre, in anfractuous lines. He endeavoured to ascertain, by another series of experiments, whether it would be possible, by some chemical mode, to re-establish the excitability of an organ which should have been deprived of it by powerful electric shocks. It results, according to his opinion, from the facts which he brings forward, that galvanic irritation cannot be considered as the criterion of death, seeing that the vital principle may still preserve a certain share of energy, without our being enabled, by the means of galvanism, to ascertain its existence. However intimate may be the connexion between the different organs of the animal body, it is not such, but that life may exist in each of them in a different degree. Several accurate experiments, made by HYMLY and ANSCHEL, controvert the opinion that the excitability is destroyed in every other part of the nervous system, because no

effect

effect whatever can be produced on one or several nerves of a dead body, laid bare, and subjected to galvanic irritation.

HUMBOLDT, after having given it as his opinion that an asphyxy destroys, for a short space of time, the irritability of the external parts, without diminishing that of the internal parts, exclaims thus: "Is it necessary, because the galvanic irritation is found not to produce externally any sensible effect, to consider as dead the individual on whom the trial is made? May not an electrical commotion, made to pass through the heart, restore the pulsations of that viscus, which, by the means of the blood in the arteries, may still convey life to every part of the animal system?"

The most important objection to the opinion which is combated by HUMBOLDT, is derived from the alternations of excitability, and from its return, after it has been apparently annihilated. In a communication made to HUFELAND, CREVE has asserted that the return of the vital force in the animal body, after it has ceased to manifest itself, is altogether chimerical. According to this position, it is necessary to deny *a priori* the effects relative to which observation alone can instruct us. It is necessary to give a flat contradiction to HUMBOLDT, when he asserts that, in the course of the experiments he has made, to ascertain

ascertain the effects of saline and other substances on the nervous and muscular fibres, he has *more than a thousand times* seen, that the weak stimulant of zinc and lead produced a powerful irritation in organs on which, a few minutes before, the more active stimulant of gold and zinc had not the smallest effect. He adds, that he has seen the irritability disappear in the same muscles, three or four times successively, and again manifest itself as often, while he was employed in bringing alternately into contact with them, opium, the arsenical oxyd, alcohol, musk, acids, and alkalis.

This proves that the apprehensions of HUMBOLDT were not unfounded, when he advanced that galvanism may lead to an erroneous judgment, when it indicates death, where there is merely a more or less complete, or a more or less transitory, want of irritability. He did not confine himself to cold-blooded animals, in prosecuting his trials; but, having directed his experiments to his own nerves, found that alkaline solutions, and the oxygenated muriatic acid, augment, in their case, the effect of galvanism, as powerfully as they do on those of frogs and fishes. "Life," he observes, "is not a principle which can be annexed to the animal body, or readily separated from it at pleasure. The vital phenomena are the result of a certain organization of matter, the

the form and mixture of which are determined. This is the reason why a change in the mass necessarily produces new phenomena; and it is perhaps true, that what we call a destruction of excitability, arising from the commencement of the putrefactive process, is no other than a less degree of excitability."

Although it would appear, from the experiments and reasonings of HUMBOLDT, that galvanism cannot be considered as an infallible mean of distinguishing real from apparent death, still that naturalist is far from rejecting altogether the opinion of CREVE, and the method proposed by him. He is, on the other hand, of opinion, that, without affording a complete certainty, the plan proposed by the latter holds out a prospect of probable success, which is not to be rejected under many circumstances, seeing that the application of it is very simple, and that it may be a great resource, in every case in which it is impossible to wait until the putrefaction has commenced, for instance, in actions, whether by land or by sea. He is by no means unfounded in his persuasion, that, after a combat, the surgeons are too precipitate in the judgment they form, relative to those who have fallen, and on the certainty of whose death they decide, because they have neither pulse nor respiration. The consequence is, that, in actions by land, they are left

on

on the field of battle, exposed to all the injuries of the air, until they are thrown into a ditch. Our naturalist is of opinion, that it might be the means of snatching many of these unfortunate victims from an untimely death, if the surgeons of the fleets and armies were to be constantly provided with a galvanic apparatus, such as a simple lamina of silver, and another of zinc, with which, after having denudated the biceps muscle of the arm, or the *gastrocnemii* muscles, they might, in a few minutes, and without any other preparation, make an experiment on each of the bodies in which life is presumed to have been extinguished.

The second question examined by HUMBOLDT is, whether galvanism is capable of recalling to life the individuals in whom the vital principle appears no longer to subsist. The analogy between the action of galvanism, and that of electricity, on the organs of animals, has been established by a multiplicity of observations; and it was from the manifest resemblance between the galvanic and electric phenomena, that VALLI conceived the idea of proposing the metallic stimulus, which, according to him, possesses great efficacy in the case of persons labouring under asphyxy. He succeeded in bringing to life two pullets which had been drowned, and were apparently dead. ANSCHEL was successful in several similar experiments, made on frogs suffocated in hydrogen gas.

gas. Soemmering proposes to repeat these experiments on persons apparently dead, by producing an irritation on the phrenic nerve, which, on account of its openings into the cœliac ganglion, and into the recurrent and brachial nerves, excites a great number of sympathetic movements. Humboldt very properly testifies his surprize, that Creve should not only condemn these experiments as totally inefficacious, but should also venture to assert, that the proposition brought forward by Valli and Soemmering, manifestly betrays, in both of them, a very small share of physiological, pathological, and therapeutical knowledge. This he is very far from proving.

A question intimately connected with the preceding one, consists in knowing whether galvanism is to be regarded as a mean of curing the gutta serena, rheumatic affections, palsies of the extremities, &c. If the metallic stimulus has been found to be useful in asphyxies, in which every part of the system, as well nervous as muscular, is in a palsied state, we may certainly be allowed to expect as favourable a result in cases of partial paralysis, such as certain affections of the stomach, of the eyes, and of the extremities of the cutaneous vessels. An objection made by Pfaff to the application of galvanism, in paralytic diseases, is, that they may be better com-

bated by the electrical stimulus, the force of which may be augmented or diminished at pleasure. But does not this observation strictly apply to the metallic stimulus? If experience has not as yet afforded us any precise information as to the relations which subsist between the effects of these two curative means;—if it be true, in opposition to the generally received opinion, that the galvanic and electric phenomena are essentially different from each other, how is it possible to decide, *a priori*, that the action of both of them, on the animal fibre, is the same? A knowledge of this subject will be acquired by a series of experiments made on palsied limbs, after vesicatories have been applied to them, or artificial ulcers produced in any other way.

Galvanism promises to be very useful in rheumatic affections, as well as in the treatment of several other diseases, in the cure of which it has been often proposed to produce externally a discharge of the humours. HUMBOLDT observes that, in the experiments he repeatedly made on himself, the secretion of the lymphatic humour continued as long as the galvanic irritation was kept up, on the ulcers formed by the vesicatories. What was still more extraordinary was, that the powers of the cutaneous vessels were augmented to such a degree, that the secretion continued for some time after the application of the metals had been

been discontinued. In a letter to our naturalist, Dr. ANSCHEL observes, that the results of several similar experiments, which he tried on himself, were precisely the same. It would not be amiss to try the effect of electrical emanations on wounds made by blisters, and to compare it with that of galvanism.

PFAFF has, with great sagacity, deduced from the galvanic experiments made by him, a mode of ascertaining whether the operation for the cataract may be successfully performed. He observes, at the same time, that this method is not infallible, seeing that the flash of light produced by the galvanic stimulus, in the experiment of Mr. G. HUNTER, of York, may not be manifested, although the retina still preserves its sensibility. HUMBOLDT observes that he has known several persons, in the case of whom the experiment described by VOLTA and HUNTER has failed in producing the sudden coruscation of light, notwithstanding their eyes were free from any blemish. This circumstance may, in the instance of cataract, give rise to a double uncertainty; since, to draw a just conclusion from the experiment in question, it is necessary to know, in the first place, whether the eye of the patient was susceptible to the galvanic impression before he had been deprived of his sight; and, secondly, whether the privation of excitability, after the

loss of sight, depended on a defect of the retina, or of the optic nerve, or originated from a co-existing and accidental circumstance, such as an affection of the second branch of the fifth pair.

Galvanism has been attended by this important advantage to anatomists and physiologists, that it furnishes them with a sure method of distinguishing the nerves from the other organs, and from the vessels more particularly. HUMBOLDT is of opinion that surgery cannot fail, in its theoretical part at least, to derive great advantages from the method proposed. This is highly probable; but there is another benefit, of equal importance, to be derived from galvanic experiments, namely, a mode of estimating the degree of excitability of a nerve or a muscle. Our author is persuaded that galvanism will never throw a greater light on practical medicine, than when its doctrine shall be studied in this point of view.

Undoubtedly, galvanism alone is not sufficient to guide us in the inextricable labyrinth of the phenomena resulting from the changes, the greater or less degree of the rapidity of which escapes our observation, that take place in the excitability of our organs. Provided, however, it may not lead us safely through all the mazes of physiological research, it will, at least, furnish us with a clue to many of them. "All the experiments I have made on this subject (ob-

serves

serves HUMBOLDT, in concluding his letter), together with the variety of facts which have been adduced, and which lead to observations of the highest importance relative to the Materia Medica and the chemical processes of vitality, would have been forever lost to me, had it not been for the attempts made to ascertain the state of the nerves, by the help of metallic irritation."

The above communication is without doubt replete with novel and interesting ideas, blended with conceptions which display great ingenuity. There are, however, different points on which the author merely touches, and on the subject of which it is to be wished that he had gone into some length of detail. He supposes them to be sufficiently understood; and, indeed, they may be so by those who have perused attentively the results of his experiments on the irritation of the muscular and nervous fibres. A knowledge of the above work is indispensable to those who are engaged in the study of the functions of the animal economy.

In a note relative to the treatment of paralysis by galvanism, inserted in the Journal de Physique *, a communication was noticed from Berlin, in which it is said that Dr. GRAPENGIESSER,

* Floreal, an. ix. p. 391.

whose curious experiments we have already noticed in our analysis of HUMBOLDT's principal work, had, in conjunction with Professor HERS, applied galvanism with success, in the treatment of the diseases which result from partial paralysis, or a debility of the nerves of any particular part. It was added, that they had also been successful in the treatment of cases of deafness, by means of the galvanic piles *.

This note, which was of but little import at he time, has since become interesting, in conequence of the appearance of a work by M. GRAPENGIESSER, on the employment of galvanism in the treatment of several diseases. The following is a brief analysis of this work, which appeared in the German language.

The author sets out by remarking that the piles which are composed of zinc, and gold or silver, are the most powerful, but that, in consequence of the extreme irregularity of their action, they ought not to be employed for any medical purpose. Those which are composed of zinc and copper are preferable to them, because their action, although weaker, is more constant and certain.

* A particular account of these piles will be given hereafter.

It

It will be here proper to observe, that one of the extremities of the pile is denominated the *zinc pole*, the other the *copper pole*; and it has been ascertained that the electricity of the former is *positive*, and that of the latter *negative*. The former produces an acid savour, and a reddish stream of light; while an alkaline savour, and a blue stream of light, result from the latter.

HUMBOLDT and VOLTA have noticed, in the dissection of the separate organs of living animals, that galvanism is a powerful resource, when an attempt is made to ascertain the seat of the nerves in their plexuses. We are assured by Dr. GRAPENGIESSER, that this mean may likewise be employed to indicate the distributions of the superficial nerves, for instance, of those of the nose and of a considerable portion of the face, by placing one of the extremities of the galvanic chain on the nasal membrane, and the other on a point of the skin by which the frontal nerve is covered. It had been announced by VOLTA, and afterwards noticed by HUMBOLDT, in a letter written from America, that the phenomenon of the torpedo appears to be an effect of galvanism. From all these considerations our author concludes, that, in living animals, the nerves are excellent conductors of galvanism; that they are influenced by this agent in a mode very similar to that of electricity; but that, notwithstanding, it appears

to penetrate more profoundly into the nervous plexuses, and to influence them in a more durable and more local manner. The influence to be drawn from hence is, that the galvanic fluid is highly stimulating, and well calculated to determine the nervous action, in those particular cases of debility of the system, and of paralysis, in which common electricity is found to be inefficacious.

Our author now proceeds to develop the numberless varieties which are remarked in the effects, whether of the simple galvanic apparatus, or of the pile provided with conductors, which he distinguishes by the name of *battery*. These varieties depend on the nature of the poles; on the order in which the chain is established; on the degree of its extent, by which its continuity is occasionally destroyed; on the duration of the galvanic application; and, which is of still more importance, on the temperament and immediate state of the nerves, in the individual on whom the experiment is made.

Take a piece of zinc and a piece of silver, and let each of them be applied to a wound made by a vesicatory. The wound which corresponds with the zinc will be the first to cease to furnish serosity, and will be soon covered by an eschar.

If a moistened finger be applied to the zinc pole of a battery, as soon as the chain is closed, a sen-

a sensation is felt similar to the one caused by a blow given to the cubital nerve. But when the same finger is laid on the silver pole, a sensation is experienced similar to the one by which an inflammatory swelling is accompanied.

If, to the two auditory conduits, the conductors of a battery be fitted, the one belonging to the zinc pole will produce a tremulous motion in the organ with which it corresponds, accompanied by marked irradiations, and by a buzzing. The other conductor will excite an acute pain.

If the conductor of the zinc pole be made to correspond with the membrane of the nostrils, and if the moistened hand be laid on the other pole, a quick and shooting pain, almost insupportable, will be felt in the nose, together with a strong desire to sneeze. The end of the other conductor, when substituted to the former in the nostrils, causes a pungent sensation of pain.

The zinc pole likewise produces, on the organs of seeing and tasting, irritations of a much more powerful kind than those which result from the silver pole; and this happens, not only at the instant when the chains are completed, but likewise during the entire continuance of their action. When they are destroyed, the effects are reversed. At that instant of time the most powerful impression is felt towards the silver pole; but immediately after, without destroying,

stroying, as RICHTER has asserted, the previously excited sensation, it proceeds towards the zinc. For instance, it frequently happens that the buzzing is prolonged, after the galvanic application has been discontinued; and it is by no means uncommon to feel, several hours after, towards the evening, and at the moment even of going to sleep, the return of the different impressions which the galvanic action had occasioned, more particularly, that of the flash of light which had been produced in the eyes.

In the nature and degrees of the galvanic commotions, and of the impressions by which they are followed, several variations, relatively to the points of the chain by which it is either completed or destroyed, have been noticed. To remedy the defect of excitability in the nerves, resulting from the constant application of the same galvanic apparatus, it is sufficient to intervert the order of the parts of which the chain is composed. Finally, the conditions which refer to the temperaments, and to the state of the nerves, give rise to such a variety of shades and differences, in the phenomena in question, that a description of them would be impracticable. They, notwithstanding, claim all the attention of medical practitioners.

Having entered into these considerations relative to the action of galvanism, and its principal modi-

modifications, as being essential to its application to the treatment of diseases, Dr. GRAPENGIESSER proceeds to the indication of those particular maladies in which it may be resorted to. According to him, galvanism may be useful in the following cases:

1st, In palsies of the extremities, occasioned by the debility or cessation of the nervous action, and in those even which have been primarily determined by other causes, such as the compression of the brain, the repercussion of an exanthematic affection, or a rheumatic affection, when these causes have been advantageously combated by the usual means.

2dly, Galvanism is indicated in cases of a debility of sight, and in the gutta serena, when these complaints are solely ascribable to a want of excitability in the optic nerve. It will readily be conceived, however, how essential it is to be fully assured of the nature of similar derangements in the organ of sight, previously to the application of so irritating a principle.

3dly, It is calculated for deafness arising from a nervous debility, and for particular buzzings in the ears. In the case of deafness, the cause is sometimes very difficult to ascertain; but is invariably of the utmost importance. With respect to the latter symptom, when it arises, as frequently happens, from the galvanic application,

tion, it is not attended by any particular inconvenience, when it ceases with the operation itself. But when it continues for several hours after, it is a bad omen. In some cases this application produces in the ears, a sensation of sound similar to that of boiling water; to that of the whistling of the winds; of the ringing of bells; or of the loud chirping of birds.

4thly, Galvanism appears to be calculated for the treatment of hoarseness, and for that of aphony arising from a defect of nervous action. Should these symptoms follow an inflammation, or supervene after the fatigue occasioned either by singing or by crying, it will suffice to make the application of the battery, or even of the simple apparatus, to the moistened skin. But if they should appear to be the result, either of catarrhal, exanthematous, rheumatic, arthritic, or venereal affections, the preferable mode would be, to apply the most simple apparatus to the wounds of vesicatories. It is true, that this apparatus acts less forcibly; but it has this advantage, which is essential in the above cited cases, that the patient will be enabled to bear its action much longer. Our author adds, that the diseases of the larynx arising from a lymphatic affection, are also calculated for the employment of galvanism, considered as a resolutive; but that it will be invariably necessary to employ at the same

same time the *general* remedies which the circumstances of each particular case may indicate.

5thly, The same means are unquestionably adapted to the treatment of paralysis of the sphincter ani, and of the urinary bladder.

6thly, Dr. GRAPENGIESSER examines the question, whether galvanism may not be usefully employed in asphyxy, which may be considered as a momentary paralysis. HUMBOLDT made several successful experiments with the simple apparatus; and our author is of opinion, that effects still more decisive would result from the application of VOLTA's pile.

He apprehends that galvanism may likewise be successfully employed, as a resolutive, in certain chronical cases of sciatica; in the white swellings of the joints; in tumors of the glands of the neck; and in incipient cases of meliceris and atheroma. He observes that he derived some advantage from it, in a case of metastasis, accompanied by inflammation, at the articulations of the elbow and thigh; but that he considers galvanism, which is in all cases a powerful stimulant of the vital forces, to be principally a powerful mean to be employed, as an auxiliary at the least, in the treatment of many of the diseases of the nervous system. Independently of its stimulating action, when it is applied over vesicatories, it operates as a powerful derivative.

After

After having thus given a list of the diseases in which he thinks galvanism may be efficaciously employed, our author describes the different modes of its application, according to the nature and the seat of each of them. In almost every case he prefers the battery to the simple apparatus, as possessing a greater energy.

In the paralysis of the extremities, he places the conductors, either on the skin simply moistened, or laid bare by vesicatories, in such a way as that the one which belongs to the zinc pole may correspond with the trunk of the nerve, and the one belonging to the other pole, with its principal ramifications. He has discovered experimentally, that this disposition of the conductors is the best; and he has besides noticed, that, in particular cases, the excitability had been destroyed to such a degree by the paralysis, that it became necessary to employ a pile of a hundred and fifty layers, to produce any effect.

When the conductors are brought in contact with the moistened skin, to which blistering plasters have been previously applied, the invariable, and somewhat durable effect of the galvanic action, is either to augment the secretion of the serosity flowing from the wounds, or to occasion a red depression of the skin, which is soon followed by the formation of an eschar, without any discharge of blood having ensued.

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In every instance, its application tends to excite the vital forces in a very considerable degree, and to augment the local heat.

In proportion to the sympathy subsisting between the nasal nerve and the optic nerve, with a view to the production of a stimulus on the latter, in the case of a debility of sight, as well as in the gutta serena, the battery is disposed in such a way, as that the conductor of the copper pole may be brought in contact with the membrane of the nostrils, while that of the zinc pole corresponds with a moistened, or denudated, part of the skin beneath which the frontal nerve passes. It should be noticed, that the metallic lamina by which one of the conductors is terminated, on being applied to the nasal membrane, is frequently productive of an almost insupportable sensation, attended by excoriation. When this unpleasant circumstance occurs, the conductor ought to be applied to the upper jaw, near the *molares*, or grinders. In doing this, however, so acute a pain is sometimes occasioned, that it becomes necessary to apply the conductor to the moistened skin of the cheek, with which, it should be observed, its points of contact ought to be frequently changed.

The safest way of irritating the optic nerve, consists in placing the button by which the conductor of the copper pole is terminated, or, which

which is still better, that of the zinc pole, on the cornea, which, conjointly with the humours of the eye, acts as a humid and conducting substance, by transmitting the irritation to the retina itself. It is true, that this mode of application requires every possible precaution, seeing that, in consequence of the very violent stimulus it produces on the organ of sight, an abundant secretion of tears ensues, accompanied occasionally by much redness of the conjunctive tunic, as well as by an insupportable pain of the ear. It is frequently followed, however, by contractions of the iris, which was before in a state of entire immobility.

In the diseases of the organ of hearing, if it should be proposed to subject the two ears to the galvanic action, the extremity of each of the conductors should be provided with a metallic stem, contained in a glass tube, the bent extremity of which, armed with a button, and extending beyond that of the tube, should be covered with linen, and introduced into the *meatus auditorius* on either side. The above metallic stems, or rods, thus armed, should be left there for a few minutes, once or twice daily, taking care that the conductor of the zinc pole should correspond with the ear which is the dullest of hearing. The acoustic nerves being highly irritable, a sensation of sound is felt to a greater or less degree.

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In some cases the irritation extends to the optic nerve itself.

Another method consists in applying vesicatories behind the ears, and laying over the wounds made by them two small metallic surfaces, one of zinc, and the other of silver, fastened together by a chain of gold and silver. These pieces of metal, of the breadth of about a third of an inch, should be secured by a ribbon, and left on for the space of several hours. The invariable effect of them is to produce a great discharge of serosity, and to occasion, on the zinc side, as eschar, the falling off of which is to be hastened by appropriate remedies, to the end that a similar application may be afterwards made. It sometimes happens that the hearing is restored during the time the pieces of metal remain on the wounds made by the blistering plasters. Our author acknowledges, however, that the effect is rarely durable.

When it is simply intended to excite the galvanic action on one of the ears, the stem adapted to the conductor, as it has been described above, should be fitted on that side only. To complete the chain, it will be sufficient to apply the moistened hand to the other pole of the pile; or to establish a correspondence between the second conductor and a vesicatory laid behind the diseased ear; or, which is still better, to apply

ply the second conductor, provided with the stem which has been pointed out, behind the soft palate, or *velum pendulum palati*, to the eustachian valve. This mode of application to a single ear is the most powerful, and is, at the same time, not attended by any inconvenience.

In the employment of galvanism in the case of a paralysis of the urinary bladder, the conductor of the zinc pole ought to be introduced, in men, into the rectum, and, in women, into the vagina. That of the other pole should be made to correspond with a vesicatory applied over the *os pubis*.

In hoarsenesses, in cases of aphony of a long standing, in obstructions of the lymphatics, in glandular tumors of the neck, and in chronic rheumatisms, an application is made, either of the simple apparatus, or of the battery, with or without vesicatories, according to the circumstances.

The following very interesting communication on the efficacy of a galvanic belt, or chain, in the treatment of a fixed pain in the back and loins, was addressed to Mr. Tilloch, the learned proprietor and editor of the Philosophical Magazine, by Mr. Richard Teed, jeweller, in Lancaster-court, Strand *.

The writer sets out by observing, that he had

* Phil. Mag. vol. xii. p. 105.

not

not then (in Feb. 1802) found, in any publication on galvanism, that a material benefit, in the cure of diseases, had resulted from that discovery. He therefore begs to submit the following case to public consideration, with the hope that others, labouring under similar complaints, will be induced to repeat his experiment, so as to derive from it as effectual a relief as he had himself experienced. He proceeds as follows:

"For a considerable time past I had been much troubled with a constant pain in the small of my back and loins, which, although it resembled the lumbago, was scarcely ever so violent. I was constantly most sensible of it after sitting long in a reclined or writing posture; insomuch that, if I arose suddenly, it was not without great difficulty. This complaint continued for eight or ten months; and, latterly, with increasing inconvenience. The idea of a galvanic belt, or chain, composed of zinc and copper, had often occurred to me, and I waited only in hopes of hearing that it had been successfully applied in similar cases; but the experiments of scientific men having taken a different direction, I made a belt consisting of fifteen small square plates of zinc, each of them connected with two links of plated copper wire, fastening the two ends with a common hook and eye, so that there was a perfect chain, or circle, of metal, round my body, by which any

interruption of the electric fluid was prevented. I also covered about three parts of the chain with leather, leaving the remainder to come into contact with the part where I felt the most pain. I had not worn the belt twelve hours before I felt a sensible relief; and the pain gradually left me. In three weeks I had not the least return, and, after having worn the belt three months, I concluded that it had answered all my expectations. But, to place the experiment beyond the possibility of doubt, I discontinued it, and had no pain whatever in my back for two months, when, at length, I perceived the pain to return occasionally. I had again recourse to the belt, and am now wearing it. As occurred in the first instance, it has removed all pain from the part affected; and I feel no inconvenience whatever.

"A short time after using the belt I observed a considerable oxydation on the zinc, which, I suppose, was occasioned by the perspirable matter from the skin, and which, I conclude, was the medium, or exciting agent, as is the case with the diluted nitric acid in the galvanic pile. By scraping off the oxyd, which I constantly did once in three or four days, I believe the effect became greater.

"In giving you this plain, but circumstantial account, I trust that so valuable a discovery will not be slighted, but that unprejudiced persons will

will likewise make the trial; and I particularly recommend it to the attention of those who have complaints of the same kind."

An account is given by Mr. SPRENGER, of Jena, of his method of administering galvanism in cases of deafness. A small ball is applied to the external orifice of the ear, and a much larger one is held in the patient's hand. The communication is then formed and interrupted alternately, by the means of machinery, once in every second, for about four minutes daily, for a fortnight or more. He asserts, that he has thus restored the sense of hearing to forty-five persons, and to four of them that of smelling also. Those who were completely deaf experienced relief, with scarcely any exception; but a partial deafness did not appear to receive the same benefit The ear was filled with wool, to prevent the patient from taking cold. The degree of benefit obtained was estimated by an instrument invented by Professor WOLFE, in which a hammer falls from a certain point of a quadrant, so as to strike an elastic plate with a velocity capable of a precise determination. The above experiments relate to so important a subject, that they ought not to be passed over without notice, however improbable it may appear that galvanism should have any material advantage over electricity excited by the common means, and however we

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may be disposed to believe the reports made by other observers, that the relief is in general inconsiderable, and merely temporary.

Several curious experiments, on the treatment of diseases by the means of galvanism, have been recently made by the members of the School of Medicine in Paris. The following is a brief statement of the one which appears to be most interesting.

The first consideration was the application of the effects of the pile of VOLTA to the animal economy; and the conclusions which were drawn were to this effect:

1st, That, in the employment of the above pile, the galvanic influence penetrates and affects the nervous and muscular organs, more profoundly than the common electrical apparatus, the latter being calculated by the customary measure of medical electricity.

2dly, That the effects of the pile produce powerful contractions, and strong sensations of pricking and burning, in parts which are, by their diseased state, rendered insensible to sparks, and even to electrical shocks.

3dly, That the duration of this action is such, as to warrant a hope that an efficacious excitement, capable of being successfully employed in the treatment of cases of paralysis, may be found in the Voltaic pile.

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In the application of this apparatus it was likewise observed, that the effects produced appeared to be proportionate to the extent of the points of contact; insomuch that the most powerful excitation ensued, when the commotion was effected by the meeting of the conductors emanating from the galvanic pile, with metallic conductors fixed on the diseased part, the contact being of a greater or less extent.

The experiment above alluded to was made under the immediate direction of M. HALLE, a very intelligent naturalist, whose researches on galvanism we have had several times occasion to notice. We give the relation in his own words:

"A man, the whole of whose muscles on the left side of the face were in a palsied state, in consequence of a fluxion brought on by the action of cold, had been electrified several times, but felt neither sensation nor contraction when the spark was directed to the affected part. Indeed, he was scarcely sensible of a slight contraction in the great zygomatic muscle, when the application of the electricity was made by commotion. This individual was subjected to the galvanic action of a pile constructed with fifty metallic plates; and a communication was established between different points of the diseased cheek and the two extremities of the pile, by the means of metallic chains and exciters. At

the instant of contact, all the muscles of the face became contracted. The patient felt not only a pain, but a very disagreeable sensation of heat. The eye was convulsed; the tears flowed involuntarily; and a pain and swelling ensued at the different points which had been touched."

Such is the account which M. HALLÉ gives of the first day's treatment. What follows is extracted from the journal of the case, as it was kept by M. THILLAYE, one of the members of the School of Medicine.

At the end of the first galvanic application it was remarked, that the redness was more strongly marked than when electricity was employed; and this redness was accompanied by a very visible swelling, with a slight degree of pain, and an augmentation of the discharge of the lachrymal humour. These symptoms disappeared, however, a few minutes after.

An observation which was made with great pleasure was, that the contraction was not of so short a duration as the one which resulted from the electrical shock. This circumstance inspired, both in the patient, and in those by whom it was treated, a hope that, provided a complete cure should not be effected, the case would be mitigated in a very considerable degree. In reality, after having continued the same application for some time, it was perceived that the mouth was

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not so distorted as before, and that the sight of the eye on the palsied side, was more perfect. This progress towards recovery went on, in an augmenting ratio, until the commencement of the third month, the number of the pieces of which the pile was composed, having, in this interval of time, been augmented to seventy-five. The phenomena which had been observed on the first application, were manifested on all the successive ones; and at the above epoch the mouth was, pretty nearly at least, in its natural position, the discharge of the lachrymal humour being at the same time very trivial, and the vision very distinct. The muscles of the right side, however, counterbalanced those of the opposite side during their repose only; for when the patient spoke, the mouth was drawn to the right side.

Before we proceed further, it may be proper to particularize the symptoms of this case, when the galvanic treatment was commenced. The upper eye-lid on the palsied side, the left, could not be depressed below the level of the pupil. The inferior lid, drawn downwards, and in a manner reversed, displayed the conjunctive tunic by which it is internally covered. The tears were no longer retained by the eye-lids, thus separated from each other, and, having ceased to be directed towards the lachrymal orifices, fell continually on the cheek.

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The lips, which had taken an oblique direction, were elevated from the left to the right; and this distortion was augmented whenever the patient opened his mouth to give utterance to his words. At these times the lower lip did not withdraw itself from the upper one, to afford a passage to the sounds of the voice. It should be added, that the cellular membrane, both of the eyelids and of the cheek, was surcharged with humours.

The complaint having been neglected for several days, the conjunctive tunic was become violently inflamed. The eye was painful; the *epiphora*, or impetus of the humours, was augmented, and the sight obscured. This latter effect was to be entirely ascribed to the abundance of the tears. The eye-lashes were glued together during the night, although the lids did not touch each other.

From the above symptoms the ultimate effects of the galvanic trials will be best ascertained. At the end of six months, when the treatment was discontinued, the lower eyelid had ceased to be depressed, and was free from excoriation. The upper lid, however, did not descend sufficiently low to close the eye completely, insomuch that there was a small space of about two lines between the lids. There was scarcely any derivation of the humours; and the mouth was in its

its natural situation. It should be added, that a considerable meagreness of the affected side, prevented a due appreciation of the changes which had been brought about in the condition of the patient, who, however, found himself much better. Throughout the whole extent of the part affected, he felt a greater sensibility than on the opposite side.

An experiment, in which the same means were employed, was afterwards made on a youth of about seventeen or eighteen years of age, who had laboured under a slight deafness from his infancy upwards. The short duration of the time, however, during which the patient was treated, and the difficulty of justly appreciating the susceptibility of an ear affected by a slight deafness, are the reasons why the results were not particularly noticed.

In the above application of galvanism to the human body, M. HALLE remarked several very singular anomalies. The pile was frequently a long time in communicating its effect, which, in other trials, was completely interrupted for the space of several seconds. It would appear that, in both these cases, the galvanic fluid met with some obstacle in its progress. Under these circumstances, it was sufficient, either to moisten the chain, to rub it, or to change the respective position of the rings, to establish the communi-

cation.

cation. It was in general observed, that, with a view to the speedy production of the sensation, it was not simply necessary that the skin should be moistened with water, but that the fluid should have been made to permeate its pores, until it was in a manner soaked. M. HALLE himself, as well as several other persons who consented to submit to the experiment, felt the kind of sensation which galvanism produces. It was, in their case, somewhat analogous to that which would have resulted from the punctures of several pins, if they had been forced at the same time into the skin. When the exciting arcs were applied to the vicinity of the salivary glands, a sharp pain was produced, accompanied by a sensation of heat, and a slight degree of metallic savour.

The following letter was recently addressed, by M. OPPERMANN, a medical student, to a physician of Paris.

"On the receipt of your letter, I nourished a hope that my father, provided he should not recover the complete use of the parts which had been attacked by paralysis, would at least recover his speech, as I proposed to have a Voltaic pile constructed in a particular manner*. Having made

* The plates of zinc were soldered to the plates of copper, after the introduction of a bit of cloth between each of them. The

made trial of it as soon as it was ready, I could not, in the first instance, perceive that it produced any sensible effect, either on the palsied side of the tongue, or on any other of the parts affected. In the evening, however, after having returned the pile into its tin case, and introduced the latter into a tub filled with water, I placed the extremities of the fingers of the palsied arm in the fluid; and, by the means of a silver conductor, directed several sparks to the side of the tongue which was not affected by paralysis. At the beginning the sparks had not any visible effect; but on being repeated for some time, I was quite surprized to see a motion in the palsied fingers, at the same time that the tongue withdrew itself from the extremity of the conductor with a great degree of celerity. Being emboldened by this early dawn of success, I applied the point of the conductor to the palsied side of the tongue. It was some time before I could obtain any satisfactory result; but at length that side also was sensible to the effect of the sparks,

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The upper plate was provided, in the centre, with several needles of copper, and, at the circumference, with small asperities of the same metal. This contrivance appeared to M. OPPERMANN to be much better adapted to the production of sparks, and consequently to the effect he wished to produce, than if the surface of the upper plate had been smooth.

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at the same time that the fingers moved repeatedly.

"On the following day, having placed the pile in the water, I resumed the process. My success was greater than that by which the first experiment was attended. The muscles of the palsied arm contracted pretty forcibly; and the tongue, on the palsied side, gave evidences that it was extremely sensible to the effect of the machine.

"In the evening I repeated the above experiment, which I afterwards tried on the foot of the palsied inferior extremity. For this purpose I placed it in the water contained in the tub; and by the means of a conductor of iron, established a communication between the pile and the tongue. This experiment succeeded perfectly well.

"On the third day I came to a resolution to produce contractions in the muscles of the face, on the side affected by paralysis. To accomplish this, I placed the point of the conductor on the parts of the face corresponding with the facial, infra-orbital, and inferior maxillary nerves. This experiment was attended by all the success I expected to reap from it, the muscles contracting so forcibly as to cause a considerable degree of pain.

"I afterwards varied the experiment, by applying the extremity of the conductor to ulcers made by vesicatories which had been laid on the parts

parts affected. In this instance I was likewise very successful. Since I had begun my galvanic experiments, I had occasion to remark, that the ulcers made by vesicatories applied to the hands and feet, suppurated extremely well; and that it was not necessary to stimulate them, as before, by the application of fresh cantharides.

"On the fourth and fifth days I continued my experiments, with a nearly similar effect. However successful they may have been at the moment, I dared not conclude that those which I should make in the sequel, would be sufficiently efficacious to subdue the disease, either wholly, or in part, because its attack had been extremely violent. I had, besides, occasion to notice, that as soon as the experiments were discontinued, the palsied parts returned to the state in which they had been before the galvanic application was made, and were incapable of any movement. With respect to the tongue I had been very sanguine; but I could not find that I had hitherto gained any advantage on that score.

"However, on the sixth day I resumed my experiments, which I continued, without any interruption, for the space of a fortnight longer. My patient felt the most acute pains, when the point of the conductor was brought in contact with the ulcers made by the blistering plasters. In this case, a violent contraction was produced

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in the muscles, at the same time that the lower limb was raised. This phenomenon was likewise displayed, whenever the point of the conductor was applied to the facial nerve, while the hand was beneath the water.

"In general, the sensibility returned to its natural state. I do not wish to deny but that it may have been exalted in an inconsiderable degree. The muscles have gained on the score of contractibility; but in the inferior extremity only. It is certain that the patient moves the limb with greater facility. He begins to support himself on his feet; and I have reason to hope, that a well combined usage of the newly discovered principle of galvanism, may contribute to restore a part of its motion to the palsied arm."

"It is necessary that I should inform you, in this place, that at the commencement of the attack, the mouth was absolutely distorted, the tongue being at the same time drawn towards the left commissure of the lips, and the right side of the face flaccid, and destitute of feeling. Since the experiments have been made, the face has resumed its natural state, the tongue its ordinary position, and the patient has articulated a few words.

"I shall conclude my letter by the remark, that the copper employed in my pile was greatly oxydated; and shall likewise observe, that the galvanic

galvanic effects were invariably in an inverse ratio to the amount of the oxydation. Accordingly, after having, each night, *dis-oxydated* my plates with an alkaline ley, the commotions were more powerful the next morning than they had been on the evening's application.

"The water in which the column was plunged was in the first instance pure, but was afterwards saturated with muriate of soda, and, finally, with the muriate of ammonia. The galvanic effects were more sensible in the latter case than when the muriate of soda was employed, at the same time that this substance had an evident advantage over pure water."

The details contained in the above letter, relative to the treatment of paralysis by the galvanic pile, are both curious and satisfactory. We shall now extract the substance of a report, made by a very accurate observer, Vassalli-Eandi, on the action of galvanism, and on the application of this fluid, and of electricity, to medicine.

Our naturalist commences by observing, that the above fluids, and the uses to which they may be applied, having become a common topic of conversation among well informed persons, and, as constantly happens with new discoveries, their advantages having been exaggerated by some, and questioned by others, he had been called on by

an associate, M. Bosse, to resolve two questions on this subject. His reply to this invitation is as follows*:

"You asked me, in one of our late academic sittings, why, after so many experiments, made by the first philosophers of the last century, on the electric fluid, such a variety of opinions is entertained in regard to its medical action on the human body; and whether galvanism seems already to promise results more useful to the healing art. I shall here give you my opinion on these questions, or rather submit to you the inductions which different experiments, made by myself, or at which I was present, gave me reason to deduce with more certainty than I durst venture to hope when I began to pay a serious attention to this object.

"I consider galvanism as a modification of electricity—a modification which renders this fluid more active; as the small flame separated by the blow-pipe is far more ardent than the large one from which it is taken. I have read to the class†, several experiments which seem to support this comparison between electricity and galvanism. Animals which were only stunned by the strongest sparks from a magic picture, were

* Philosophical Magazine, vol. xv. p. 330.

† Of exact sciences of the Academy of Turin.

killed

killed in less than three minutes by a very weak degree of galvanism.

"The fluid of a pile composed of 25 plates of silver and zinc, of the size of a crown-piece, intermixed with pieces of pasteboard moistened in water saturated with muriate of ammonia, oxydates the metals in decomposing the water, while it is scarcely sensible in the fingers, and gives only small sparks. The brilliant electric sparks which excite in our bodies a strong sensation of pricking, neither oxydate the metals, nor decompose the water, if they do not communicate a shock. Having made the galvanic current to pass through the body of a frog, its fluids were decomposed, and I saw it swell up so much, that it could no longer plunge into the water, though possessed of great vitality, which I never observed to be the case in frogs when tormented by strong electric sparks. All these facts, to which many more of a similar kind might be added, confirm the great activity of galvanism when compared with electricity. Hence it results, that the fluid of the Voltaic pile may be very useful in cases in which common electricity would not have sufficient activity. You are acquainted with some of the experiments which I made in conjunction with my colleagues GIULIO and ROSSI: we made others, still more interesting, which have determined several physiological facts, before doubt-

ful for want of being verified. We then tried an application of it in several diseases with the greatest success. Three of the cases are as follow:

"A lady, about thirty years of age, after severe pains in the head, lost the sight of the right eye. M. Rossi being consulted in regard to this malady, after a close examination of the eye, which appeared to be as sound, and to look as well as the left, concluded that it must arise from a palsy of the optic nerve, or what is called a *gutta serena*, which suffered the patient to see only, as it were, through a thick mist. What increased her misfortune was, that it deranged the sight of the other eye, so that she was always afraid of falling, not being able to distinguish well with the right eye the objects which she handled. Rossi being sick, sent her to me, that I might make an application of galvanism. I formed a pile of thirty pairs of plates, like those already mentioned, and, employing gold wire as conductors, I caused the galvanic current to enter near the exterior angle of the eye, and to issue sometimes at the eye-brow, sometimes by the ophthalmic branch which passes through the orbital foramen, and sometimes near the interior angle of the same eye. The operation was very painful; it caused abundance of tears to flow; but, after successive galvanic shocks for half an hour, the eye began to see

see a little better. That I might not fatigue my patient too much, and that Nature might have time to act, the operation was suspended till the evening, when it was repeated for half an hour. The next day the eye began to distinguish the figure of bodies. Having repeated the operation for three days following, the lady was not only able to distinguish the figure of bodies, and people's features, but also the pupils of their eyes. Before this operation, in consequence of a consultation with Dr. John Baptist Anforini, first physician of the Hospital of la Charité, I had galvanized a young woman, twenty-seven years of age, of a melancholy temperament, who, after some slight attacks, had a hemiplegia of the right side, which affected in particular the arm, the cheek, and the eye. The other symptoms were removed by bleeding and the use of the remedies usual in such cases; but the eye always remained fixed, with pains in the muscles. The application of galvanism for ten minutes was sufficient to excite abundant tears, and a discharge of a watery fluid from the nose, on the side which had always been shut since the attack of the disorder, at the same time that it greatly alleviated the pains of the muscles. She could even turn her eye to both sides; but she found great difficulty in raising or lowering it, with a sensation of heaviness all around the eye. This operation

being repeated, after the interval of a day, the eye acquired its former freedom of motion, and the patient was freed from every sensation of uneasiness.

"These two operations were performed in the presence of several persons, and executed almost entirely by M. HYACINTH CARENA, lecturer on natural philosophy in the National College of Turin.

"The advantages of galvanism will appear to you still more decisive, by the cure of a person labouring under hydrophobia, performed lately by M. ROSSI, who will give a full and complete account of it in a memoir, on which he is now employed.

"A man, bit in the finger by a mad dog, came to consult him, in consequence of a pain which he felt in the arm, the back, and particularly the finger, which had been bitten more than a month. A caustic applied to the finger removed the pain; but a few days after it returned, accompanied with symptoms of hydrophobia. The patient could no longer look at water without horror; an inflammation in the throat prevented him from swallowing even chewed bread; and he experienced a strong propensity to bite those around him.

"In this state he was brought to M. ROSSI, who, observing that he could not bear the sight of water, nor that even of shining bodies, pro-

vided

vided in another room a pile consisting of 50 pairs of plates of silver and zinc, intermixed with 50 pieces of pasteboard moistened with a solution of muriate of ammonia. He employed slips of brown paper, moistened, as a conductor, on which the naked feet of the patient were placed, and at the moment when he opened his mouth to bite, one end of the arc was thrust into it, while the other communicated with the pile. The patient suffered a great deal from this operation, which, after several shocks, weakened him so much that he could no longer support it. Being stretched out on the floor, he was then galvanized with ease: the operation made the sweat run from him in drops. After some time Rossi caused the patient to be conveyed home, and gave orders that he should be brought back next day, to the end that the operation might be repeated. It was two o'clock in the afternoon when the patient was galvanized, and at six next morning he came to Rossi himself, to tell him that he was completely cured, as he experienced no pain or difficulty of swallowing, and was entirely freed from his aversion to water and to liquids: no persuasion, however, could induce him to submit to a new operation.

"But a few days after, some slight pains having given him reason to apprehend a new attack of hydrophobia, he returned to Rossi, who, by re-

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peating the operation, made all the symptoms disappear. This cure was also effected in the presence of several persons. The patient was endowed with so great sensibility, that, for more than a month after, he felt in the shoulders a sensation of the galvanic shocks, which I experienced only as far as the articulation of the finger, though I am not one of the least sensible. You see by these trials, what are the advantages which may be hoped for from galvanism. I entertain no doubt that a mean so active may preserve from the grave many individuals, by galvanizing them at the moment, when the play of the vital organs is suspended by an accidental cause.

"This will become more evident by an explanation of the medical action of electricity on the human body.

"Several celebrated writers have classed electricity among those remedies which are most certain and most active; others have shewn the inutility, and even danger, of this fluid, considered as a remedy; and both seem to be supported by well attested facts.

"Nothing, however, can be more easily explained than this apparent incongruity, if we reflect, that most of those who have applied electricity to medicine have been guided by quackery, without consulting the nature of the disease, or of the agent which they employed. For this

reason

reason I stated in the memoir which is about to appear in the Transactions of the Academy *, that the greatest circumspection should be observed in the use of galvanism, which, like electricity, may be attended with bad consequences; and I even advanced, that the latter, though a very good remedy of itself, has done more hurt than good, by improper application.

" I shall not here speak of the chemical properties which, during the enthusiasm of novelty, have been ascribed to electricity, such as that of transfusing into the human body the action of remedies inclosed in glass tubes, by rubbing it with them.

" It is well known that it is the fate of new discoveries to be exaggerated, so that their adversaries easily find reasons to oppose them. But after some time things come to their proper level; and being established on a more complete knowledge of the agent, those well acquainted with the properties of electricity are able to distinguish the cases in which it may be administered with advantage, from those in which it would be prejudicial. Of ten patients affected with the same disease, who undergo the same electric treatment, five may be entirely cured, and the other five be exceedingly ill.

* Of Turin.

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"Those who are cured extol electricity as the best of remedies; while those who have suffered, say that it only aggravates the evil. Both speak from correct experience, and at the same time right and wrong, from attempting too much to generalize; that is, because they do not distinguish the cause of the disease which requires or opposes the application of electricity. Thus the same pain, the sciatica * for example, may be occasioned either by a stagnation of the fluids, by their too great abundance, or by the want of re-action in the solids: it may arise also from organic defects; an alteration of the fluids; a poisonous, or, as it is called, *acrid* principle; or from a peculiar virus in the fluids.

"The five patients who labour under a stagnation of the fluids, receive the greatest relief from electricity, which puts them in motion; the other five, tormented by sciatica occasioned by vitiated humours, will grow worse under electric treatment, which will increase the acridity of the humours, carrying off a part of the water which kept the poison diluted. This theory of the effects of electricity in the human body is founded on

* Dr. BALBIS observed to me, that sciatica of every kind may be accounted for without recurring to the hypothetic alteration of the fluids. I replied, that I wished only to compare my theory with the principal theories of sciatica, without concerning myself with their probability."

on the nature of this fluid, and on its properties, established by numerous experiments. The electric fluid tends always to put itself into a state of equilibrium, and this tendency is so strong, that it penetrates to a certain distance in the air, and extends along idio-electric bodies. It is this tendency which causes water, when electrified, to flow from capillary syphons, whereas a very few drops only flow without this electrization. It is by the same tendency that the electric spark, when it passes from one conducting body to another, by non-conducting substances, carries with it, in its passage, conducting particles which serve it as a vehicle, if the solidity of the bodies does not oppose a very strong resistance. This property, proved by the common effects of thunder, and by several experiments, serves to account for the great evaporation of electrified liquids, and for the greater perspiration of animals and vegetables which have been electrified. It is then evident, that, whenever a stagnation of the fluids takes place, if other symptoms do not oppose it, electricity will be a good remedy; on the other hand, if the disease arises from vitiated fluids, or a virus diluted in them, electricity in this case, either by the evaporation of the diluting fluid, or by the greater alteration it may produce, will be hurtful. From what has been said, it is evident

dent that electricity and galvanism ought to be employed with the greatest circumspection, and that the nature of the disease ought to be compared with the nature and properties of these fluids, to ascertain whether the application of them is proper or not. It is to be observed also, that this remedy, in consequence of its activity, may be dangerous, like all other remedies, however good, if abused.

"I could adduce several instances of misfortunes occasioned by the abuse of electrization, even in cases in which, a little time before, it had been indicated; but I shall mention only one fact in regard to galvanism:—A young woman was cured by galvanism of pains which she experienced in the muscles of the face. After the cure, having continued to galvanize herself, she did hurt, which increased with the application of the galvanism, and did not cease till she abandoned herself entirely to the powers of nature assisted by good nourishment. The patient, then, who is incapable of forming a proper opinion respecting the state of his health, should consult a good physician, one of those who do not despise natural philosophy and the new discoveries, in order that he may never suffer by the application of electricity or of galvanism, which, as BOERHAAVE says of another very active remedy, *Mira præstat*

stat in multis incurabilibus; at prudenter à prudenti medico abstine si methodum nescis.*"

The following observations on the danger of galvanism in the treatment of diseases, by M. DESMORTIERS, were lately read before one of the learned societies of Paris.

"Scarcely (observes the author) do we know how to construct the galvanic apparatus, at the same time that we are still ignorant of the nature of this extraordinary agent, than we introduce it rashly into the animal system, without foreseeing the disorders of which it may be productive, and, consequently, without being acquainted with the means of applying a remedy to them. It is known that galvanism has the faculty of promptly reducing to a gelatinous state the muscular and tendinous parts; and that it decomposes, with a singular energy, the animal fluids. Those who subject themselves to its action, when it is either forcible, or prolonged to a certain extent, feel different indispositions, more or less violent, or of a longer or shorter duration, according to the differences of the temperament. It would therefore be prudent, before an application be made of it to the living body, to endeavour to ascertain, by direct ex-

* Elem. Chemiæ, pars iii. processus 198.

periments,

periments, what changes it may occasion in the different principles of life."

This inquiry has been followed up by M. DESMORTIERS, by particular experiments on urine, and on the bile. He observes that, in proportion as the fluids subjected to galvanism are more compounded, the more considerable are the action and re-action of their principles on metals, and of the latter on the fluids themselves. Thus, salt water possesses a greater energy than pure water, urine than salt water, and the bile, again, than urine. The disengagement of the gaseous fluid, in the case of the bile, is made with such a rapidity, that it darts out at intervals, in the form of the train of a firework, and presents to the eye a series of elongated corpuscles, which appear to be of a fibrous nature, as belonging to the mucous bodies amassed in a large quantity in the bilious secretion. As the latter acts powerfully on the metals, the process is attended by a very abundant precipitate, which the author describes with great precision, together with the changes which ensue on its being subjected to the action of the blow-pipe.

Galvanism changes the weight and colour of animal fluids, according to the extremity of the pile with which they are made to communicate. On this head our author proposes to continue his researches; and, in the mean time, he makes an observa-

observation, relative to the employment of galvanism, which it is essential to cite. He informs us that, having on two occasions applied to his own temples the galvanic conductors, he felt two powerful commotions, each of them preceded by a very strong flash of light. But this is not the most important part of the detail. "After the above shocks (he observes), I perceived that my eyes, which are habitually very weak, and in which I almost constantly feel a sensation of heat, and a darting and acute pain, were entirely free from these unpleasant symptoms. This kind of sudden cure was not, however, lasting, and was soon followed by a degree of giddiness, and a slight pain in the head, which did not go off till the evening."

The above fact is cited by M. DESMORTIERS, to prove the danger of galvanism in its application to diseases; but as it is unaccompanied by the necessary details relative to the mode in which the application was made, and as the slight inconveniences he felt may have arisen from a particular cause of which he was not himself aware, his case can scarcely be deemed an authority against the curative mean proposed, in the treatment of particular ophthalmic diseases by galvanism.

In a communication subsequently made, he states that he had subjected the urinary calculus to

to the galvanic action. A round, and very hard particle of gravel, weighing one grain, was totally dissolved in the space of twenty-four hours. Within the same time, a fragment of calculus, weighing five grains, and of a very hard texture, had lost about the fifth part of its weight.

To conclude by a recapitulation of the effects of the new curative mean, derived from the application of galvanism. From what has been hitherto said on this subject, it cannot but be acknowledged that the results of this application, in the treatment of diseases, have not been altogether conclusive in favour of its efficacy. It has been seen above, however, that M. CREVE asserts his having employed it successfully, in distinguishing real death from apparent death, or asphyxy. It is true, that HUMBOLDT, in his letter to M. LODER, combats with very powerful arguments, the opinion of CREVE, and proves that a partial death may subsist in one of the muscles he has pointed out, without its being imparted to the rest of the body; that the susceptibility to the mechanical stimulus may be annihilated, without the irritability being in general exhausted; and, lastly, that the galvanic stimulus, applied in the manner described by CREVE, is not the most powerful known stimulus, seeing that the electricity of the Leyden phial, and the Voltaic pile, act still more energetically.

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These considerations, he observes, throw a certain degree of doubt on the method pointed out by CREVE.

It has been also seen, that PFAFF has proposed the galvanic stimulus in several diseases, more particularly in the paralysis of the optic nerve. As there is sometimes a complication of cataract with amaurosis, the characteristics of which are not always evident and certain, he recommends the employment of the galvanic stimulus, as an expedient by which every doubt may be removed. If, in the case of cataract, in which its complication with amaurosis is not manifest, the application of two different exciters, in conformity to the well known process, does not produce any particular sensation in the eye, it is more than probable that amaurosis exists also. In the contrary event, it may be ascertained that this latter malady is not combined with the cataract.

The hydrophobic case related by M. VASSALLI-EANDI, is, as well as the other details he has given, relatively to the treatment of diseases by galvanism, extremely interesting; as is likewise the cure of a case of lumbago by the galvanic belt contrived by our ingenious countryman Mr. TEED. But the scientific world is more particularly indebted to M. HUMBOLDT, who has enriched his work, an extract from which we have

given, with several very judicious applications of galvanism to philosophy, pathology, and therapeutics. He shews that the galvanic stimulus has a very considerable influence on the secretions, which it alters in a singular manner; and that it may, in this point of view, be employed as an opposite stimulus, to correct the vitiated secretions. In the course of his experiments he contrived to render manifest a kind of galvanic atmosphere around the nerves, the presence of which was attested by a variety of phenomena. Lastly, by the administration of a description of galvanic *injection*, which he effected by establishing a communication, with zinc and silver, between the mouth and the anus, he succeeded in bringing to life several small birds in a state of asphyxy.

Without being too sanguine in our expectations, we may indulge a hope that galvanism will hereafter supply the means of discovering the signs of life, still existing in man, when every appearance seems to indicate certain death. It may not be improper to notice, however, that the effects which have been perceived in the parts of certain animals, deprived of every sensation, and of all motion, have not been observed in those of man, in a similar state, when galvanism has been tried. It is even more than probable, if we can judge by the precise knowledge we have acquired,

acquired, relatively to the structure of the parts of the latter, that the galvanic experiments which may be made on them hereafter will not afford results similar to those produced on the parts of animals. Time, alone, can clear up these doubts.

In one of the late Paris Journals an essential observation has appeared, on the subject of the dangers incurred by those who, without a due acquaintance with the science, venture on galvanic experiments. The author observes, that he has been successful in the treatment of several diseases by electricity; but that he has rarely given shocks. That the commotions produced by galvanism are equally dangerous, he attempts to prove in the following manner: "It is well known," he observes, "that if a piece of silver be laid on the gums of the lower jaw, and a piece of zinc on those of the upper jaw, phosphoric flashes of light are perceived, as often as the two pieces of metal are brought in contact. Well, a young man to whom I shewed this experiment, and who repeated it several times successively on himself, had, for the space of twenty-four hours, so great a debility of the jaws, that he could scarcely masticate his food, his teeth appearing at the same time to be loose in their sockets. The necessary consequence of this experiment,

one of the most simple in galvanism, is, that a powerful commotion, produced by a pile of zinc and silver, may be followed by disastrous consequences, more especially in persons whose system of nerves is highly sensible and irritable."

END OF VOL. I.

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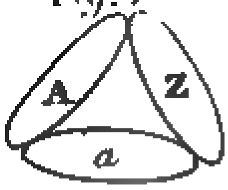
Fig. 1



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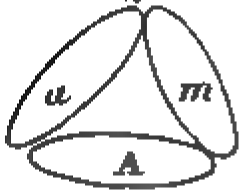

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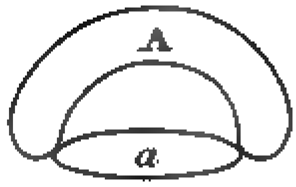

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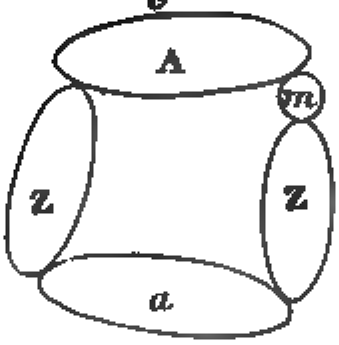

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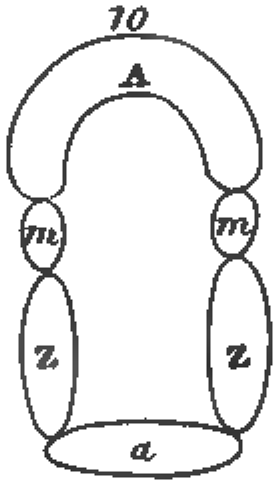

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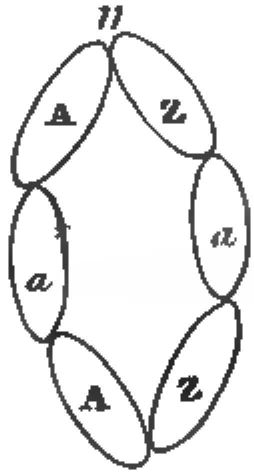

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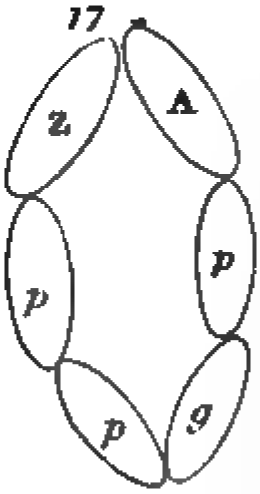

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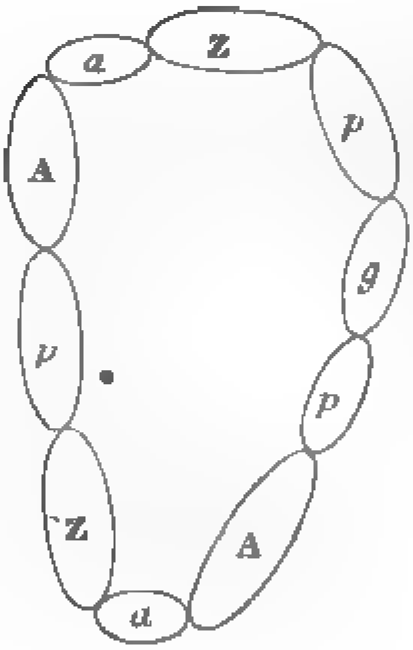

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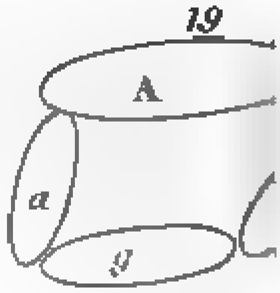

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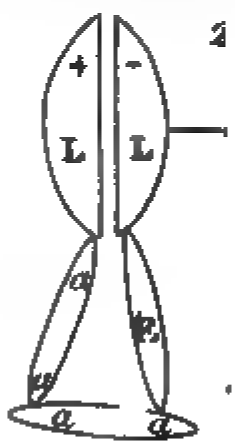


Fig 1
Fig 2
Fig 3
Fig 4
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